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# Seasonal variation in spider fauna in different habitats of Jhalana Forest Range, Jaipur, Rajasthan

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ABSTRACT: A survey of spiders was undertaken in Jhalana Forest Range, Jaipur, Rajasthan from March 2005 to February 2006. Thirty nine species belonging to 29 genera and 15 families of spiders were collected and identified. *Cyrtophora citricola* and *Stegodyphus sarsinorum* were most common.


KEYWORDS: spider diversity, seasonal variation

## INTRODUCTION

Spiders are ubiquitous in natural and agricultural habitats. They are useful indicators of overall species richness and health of terrestrial communities. (Noss, 1990). There is no documentation on spider faunal diversity and general ecology of Rajasthan state (Nigam, 2004).The present work was undertaken to study the seasonality of spider fauna in four major habitats of Jhalana Forest Range.

## MATERIALS AND METHODS

The survey of the study area was undertaken in Jhalana Forest Range, Jaipur, Rajasthan during March 2005 to February 2006. Jhalana Forest Range is located in Aravali Range of Jaipur district in the south of Jaipur city at 26°50″ and 26°55″ latitude and 75° and 75°50″ altitude and covers 14 km$^2$ area. The forest is dry tropical deciduous type. It predominantly consists of undulating terrain with parallel series of mountains having ridges, valleys and nallahs. The climate of this area is distinct in winter, summer and monsoon. Maximum and minimum temperature recorded in winter and summer was 27°C and 4°C and 47°C and 15°C, respectively and average relative humidity (RH) was 54.8%

Sampling of the forest area was mainly done following the concept of Coddington and Levi (1991) i.e. pitfall trapping, sweep netting, cryptic searching, ground hand

collecting. However, aerial hand collection and vegetation beating methods were some modifications. Most methods were applied during day from 7 AM to 10 AM and 5 PM to 7 PM during summer and 7 AM to 10 AM and 4 PM to 6 PM during winter. The study area was divided into four major habitats namely, woodland, wetland, grassland and caves, crevices or rocky area. In each habitat five plots of 1 m × 1 m were randomly selected and spider population was recorded.

The collected spider specimens were fixed in 70 percent ethyl alcohol with a few drops of glycerin (Prashad, 1971) and identified under stereoscopic microscope on the basis of epigyne of female, eyes arrangement and other characteristics with the help of keys of Pocock (1903), Tikader and Malhotra (1980), Tikader and Biswas (1981) and Tikader (1977, 1980, 1982, 1987).

## RESULTS AND DISCUSSION

The spider species so collected were examined and identified. The collection represented 39 species belonging to 29 genera and 15 families (Table 1). Most common family recorded in forest ecosystem was Aranidae followed by Lycosidae, Salticidae and Thomisidae. It is likely that representatives of these families can inhabit diverse habitats. Among the members of Aranidae *Cryptophora citricola* and *C. cicatrosa* were tent web weavers, while others were orb web weavers.

Various other spider species were observed to occupy more than one habitat of the study area. Amongst these *Mymarchne* spp. and *Plexippus paykulli* were found in every habitat of study area. These species were jumping spiders, and did not need specific web sites. *Agelena* sp., *Neoscona excelsus*, *N. pavida*, *N. mukerjie* and *Neoscona* sp. were found in three habitats viz. woodland, wetland and grassland.

Maximum number of 25 spider species were observed in woodland type of habitat because of favorable conditions, food and site for web building, while in rocky habitat the lowest number of spider species were observed due to lack of favorable conditions.

*Artema atlanta* and *Pholcus phalangiodes* preferred dark and shaded places. They have special features of 'whirling', which is a defense mechanism. Similar mechanisms have been reported in several other spider species, such as gnaphosids, mimetids (Czajka, 1963; Jackson and White house, 1986) and some primitive salticids. (Jackson and Blest, 1982). *Pardosa* spp. and *Lycosa* spp. were found along the edges of water bodies; generally they were observed moving over the water surface but dived under water when disturbed. *Neoscona* spp. and *Tetragnatha mandibulata* were usually found in the shrubs, which over hanged the water surface.

Some spiders like *Thomisus projectus* and *Xysticus minutus* (crab spiders) were found on flowers waiting for insect visitors. Coloration was observed in these spiders and they mimicked the petals of flowers. *Oxyopes* spp. were observed running along grasses, leaves and stems. Individuals of family Salticidae were solitary in nature, which were observed jumping from plant to plant. Individuals of *Hersilia savignyi* were observed on the walls of nallah, buildings and tree trunks. It was usually dark in colour mimicking the colour of the surroundings.

TABLE 1. The habitat, microhabitat and web pattern of the collected spiders

| Family, genus, species | Habitat: Wood-land | Wet-land | Grass-land | Caves/ Crevices | Micro habitat |
|---|---|---|---|---|---|
| **Oecobidae** | | | | | |
| *Oecobius putus* Cambridge | | | √ | | Wall corners |
| **Erisidae** | | | | | |
| *Stegodyphus sarsinorum* Karasch | | √ | √ | | Canopy of thorny trees |
| *Stegodyphus* sp. | | √ | √ | | Canopy of thorny trees |
| **Uloboridae** | | | | | |
| *Uloborus* sp. | √ | | | √ | Tree trunks, cervices opening, corners |
| **Hersilidae** | | | | | |
| *Hersilia savignyi* Lucas | √ | | | √ | Tree barks |
| **Pholcidae** | | | | | |
| *Artema atlanta* Walck | | | | √ | Wall corner, under stones and tree hole |
| *Pholcus phalangioides* (Fusselin) | | | | √ | Wall corner, under stones |
| **Salticidae** | | | | | |
| *Myrmarchne* sp.1 | √ | √ | √ | √ | Ground and foliage (near ant groups) |
| *Myrmarchne* sp.2 | √ | √ | √ | √ | Ground and foliage (Near ant groups) |
| *Plexippus paykulli* (Savignyi and Audouin) | √ | √ | √ | √ | Ground and foliage |
| *Telomonia vittata* (C.L.Koch) | √ | √ | | | Foliage |
| **Thomisidae** | | | | | |
| *Thomisus projectus* Tikader | √ | √ | | | Flowers, leaves |
| *Tmarus* sp. | √ | | | | Stem, twigs |
| *Xysticus minutes* Tikader | √ | | √ | √ | Leaf litter, under stones and Tree barks |
| **Heteropodidae** | | | | | |
| *Heterozeropoda* sp. | | | | √ | Rocks, Caves |
| **Clubionidae** | | | | | |
| *Chiracanthium* sp. | | √ | √ | | Arboreal specially on foliage |
| **Oxyopidae** | | | | | |
| *Peucetia viridanas* (Stolicza) | √ | | | | Arboreal |
| *Oxyopes shweta* Tikader | √ | | √ | | Arboreal |
| *Oxyopes* sp. | √ | | √ | | Arboreal |
| **Therididae** | | | | | |
| *Argyrodes* sp. | √ | √ | | | Web of *Cyrtophora* spp. |

*Contd...*

TABLE 1. (Contd...)

| Family, genus, species | Habitat Wood-land | Wet-land | Grass-land | Caves/ Crevices | Micro habitat |
|---|---|---|---|---|---|
| **Agilinidae** | | | | | |
| *Agelena* sp. | | √ | √ | √ | Opening of other's burrows or on ditch of hoof mark |
| **Lycosidae** | | | | | |
| *Pardosa sumatrana* Thorell | | √ | | | Ground, under stones and leaf litter |
| *Pardosa* sp. | | √ | | | Ground, under stones and leaf litter |
| *Hippasa agelenoides* (Simon) | | √ | √ | | Ground, under stones and leaf litter |
| *Hippasa pisurina* (Pocock) | | √ | √ | | Ground, under stones and leaf litter |
| *Hippasa* sp. | | √ | √ | | Ground, under stones, damp area and leaf litter |
| *Lycosa* sp. | | √ | √ | | Ground, under stones and leaf litter |
| **Aranidae** | | | | | |
| *Cyclosa* sp. | √ | | | √ | Web through plants |
| *Neoscana* sp. | √ | √ | √ | | Web through plants |
| *Neoscona exulsus* (Simon) | √ | √ | √ | | Web through plants |
| *Neoscona pavida* (Simon) | √ | √ | √ | | Web through plants |
| *Neoscona mukarji* | √ | √ | √ | | Tall grasses and bushes |
| *Zygillia melanocronia* | √ | | | | Bushes and thorny trees |
| *Cyrtophora citricola* (Forskal) | √ | √ | | | Bushes and thorny trees |
| *Cyrtophora cicatrosa* (Stoliczka) | √ | √ | | | Bushes and thorny trees |
| **Tetragnathidae** | | | | | |
| *Leucauge decorata* Blackwall | √ | √ | | | Bushes and thorny trees |
| *Tetragnatha mandibulata* (Walkenear) | | √ | | | Grass, reeds |
| **Sparassidae** | | | | | |
| *Olios* sp. | √ | | √ | | Foliage |
| **Scytodidae** | | | | | |
| *Scytodes thoracina* | √ | | | √ | Foliage and under stones |

The social spider *Stegodyphus sarsinorum* was found only on thorny trees e.g. *Acacia nilotica* and *Zizyphus* sp. Present results are supported by Rypstra (1983) and Halaj *et al.* (1988). They found that web-building spiders are directly linked to the configuration of the vegetations because of specific web attachment requirement. Spiders of family Therididae and Aranidae constructed their webs in tall grasses, bushes, foliage etc. *Argyrodes* sp. was commonly found in the web of tent web spiders

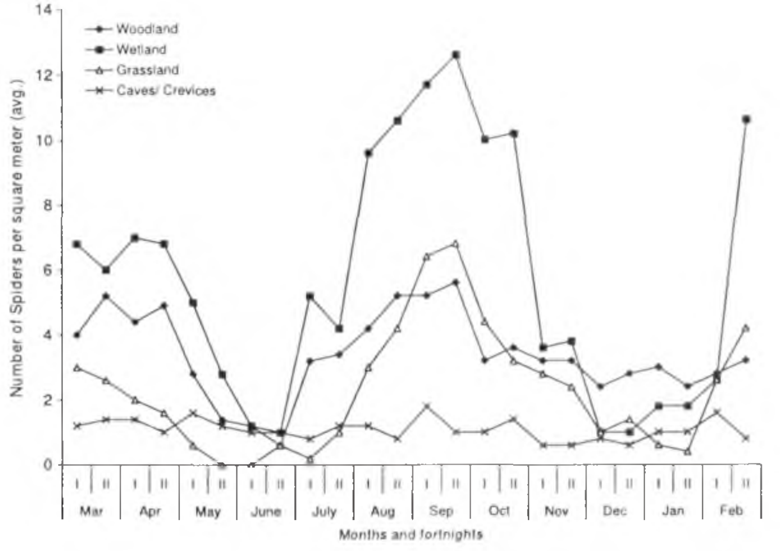


FIGURE 1. Seasonal variation of spider population in Jhalana Forest Range from March 2005 to February 2006

*Cyrtophora citricola*. It showed kleptoparasitism. *C. citricola* formed huge colony on a single tree, sometimes covering it completely.

Seasonal dynamics of spider population in different habitats during the study revealed that the spider population steadily increased from July and attained its peak in post monsoon season i.e. September (Fig. 1). The spider populations were influenced by the climatic conditions like temperature, relative humidity and rainfall. It seems that the month of September was most salubrious and favourable for spider community. The vegetation and prey density were highest during this period; hence it was assumed that the increased vegetation density provided ample food, space and source for web attachment. The number of wetland spiders increased as the number of water aquifers increased. After the post monsoon season the density of spiders gradually decreased till December due to adverse climatic conditions.

The study of four major habitats emphasized that wetland habitat which possessed maximum of spider population was amiable and favourable which led to microclimatic conditions for spider population deemed to be most favourable. The result revealed that climatic conditions influenced the activity and hence led to variable seasonal abundance during different periods of the year. Most of spiders are limited to a particular habitat only as different spider species have different tolerance limits in different habitats. Exceptions included severe or marginal habitat where limited availability of suitable web site may have influenced the number of web building spiders (Koch and Majer, 1980).

Other habitat may affect the number of spiders due to the presence of limited availability of structural features necessary for web building. Turnbul (1973) stated

that most webs required surface attachment and space requirements. It was also observed that the species *S. sarsinorum* and *C. citricola* were found throughout the year, showing their compatibility with woodland and wetland habitats. Maximum variation in spider population was recorded in wetland habitat, because of variable physical conditions in this habitat.

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# A new species of *Dinarmus* Thomson (Hymenoptera: Chalcidoidea: Pteromalidae) from India

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ABSTRACT: *Dinarmus crotalariae* sp. nov. is described from Karnataka, India and a modified key to the Indian species of *Dinarmus* given.


KEYWORDS: Hymenoptera, Chalcidoidea, Pteromalidae, new species, *Dinarmus*

## INTRODUCTION

The genus *Dinarmus* Thomson (Pteromalidae: Pteromalinae) is distributed in all temperate, subtropical and tropical regions of the world. It is known to attack bruchid beetles, especially on pods of Papilionaceae (Boucek, 1988).

Three species groups of *Dinarmus, viz., D. acutus, D. altifrons* and *D. vagabundus*, were recognized in the revision of the Afrotropical species of *Dinarmus* by Rasplus (1989). From India and adjacent countries, six species are currently known (Boucek *et al.*, 1979; Farooqi and Subba Rao, 1986; Rasplus, 1989). Sureshan and Narendran (2001) provided diagnostic and biological information for these six species, redescribed *D. maculatus* (Masi) based on the lectotype, and provided a key to identify the species. Sureshan (2003) listed the distribution pattern of all the species of *Dinarmus* in India and adjacent countries.

In this paper a new species is described and a revised key is given. The morphological terminology used in this paper follows that of Boucek (1988).

The holotype and one of the paratypes of the present study are deposited in the collections of Project Directorate of Biological Control, Bangalore, India. Registration numbers are PTED1 and PTED2 respectively; second paratype will be deposited in National Pusa Collections, Indian Agricultural Research Institute, New Delhi, India. Registration number not yet received.

## MATERIALS AND METHODS

The specimens were collected by sweeping net on pods of *Crotalaria mucronata* Desv. and then they were collected with the help of aspirator. A complete record was also maintained indicating the reference number, locality, date of collection and name of the host plant.

### Genus *Dinarmus* Thomson

*Dinarmus* (Thomson, 1878): 50, 56 (as subgenus of *Dimachus* Thomson). Type species: *Dinarmus acutus* Thomson, designated by Ashmead (1904).

*Bruchobius* Ashmead, 1904: 314–315. Type species: *Bruchobius laticeps* Ashmead, by original designation.

*Metastenoides* Girault, 1915: 190. Type species: *Metastenoides simus* Girault, by original designation.

*Oedaule* Waterston, 1922: 31. Type species: *Oedaule stringifrons* Waterston, by monotypy.

*Sphaerakis* Masi, 1924: 214. Type species: *Sphaerakis mayri* Masi, by monotypy.

### Diagnosis

Head large, not prominent behind eyes; anterior margin of clypeus shallowly emarginate or toothed; female antenna with 3 anelli and male with 2 anelli; third anellus sometimes quadrate. Mesosoma stout, convex; pronotum as broad as mesoscutum, collar broad, bluntly ridged or rounded, not sharply carinate; neck hardly visible from above; prepectus small, subquadrate; propodeum short, reticulate, constricted into subglobose nucha. Forewing with stigma more or less capitate; costal cell sometimes enlarged. Gaster short and legs stout.

### Host

All species of *Dinarmus* attack bruchid beetles in pods of leguminous plants.

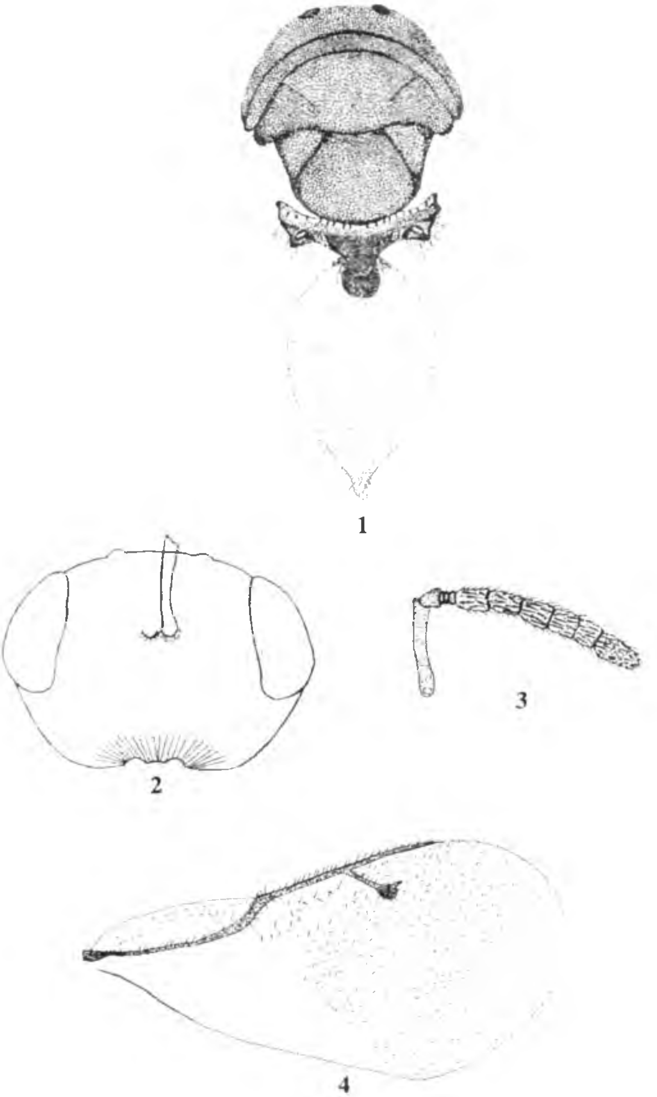
### Distribution

All temperate, subtropical and tropical zones.

### *Dinarmus crotalariae* sp. nov. (Fig. 1)

### Holotype Female

Length 2.02 mm. In dorsal view body length 1.6X width and 0.5X as long as head plus mesosoma combined. Body black without metallic shine except gaster metallic black, scape and pedicel testaceous; anelli and clava brown; similar brown bands at junction of funicular segments; coxae concolorous with mesosoma, mesosoma black; fore femur completely brown, apical three fourth of fore tibia brown, rest pale white. More than three fourth of mid femur is brownish apically and apical three fourth of



FIGURES 1–4. *Dinarmus crotalariae* sp. nov. 1. Female in dorsal view; 2. Head in frontal view; 3. Antenna; 4. Fore wing.

mid tibia is brown. Three fourth of the middle portion of hind femur blackish brown, remaining part brown. Apical one fourth of the hind tibia light brown, remaining part of the hind tibia pale white. Tegula blackish brown; wings pale brown with short pubescence.

Head (Fig. 2) moderately reticulate punctate with short white pubescence; anterior margin of clypeus weakly bidentate, striate, striae not reaching lower margin of eyes. POL 1.9X OOL, eyes separated by 1.57X their height. Antennae (Fig. 3) inserted distinctly above lower margin of eyes, scape exceeding frontocellus. Pedicel shorter than F1; third anellus transverse, distinctly longer than second but not as long as first and second combined; clava shorter than preceding two segments combined.

Mesosoma reticulate punctate; pronotum as broad as mesoscutum; propodeum with nucha distinct; forewing with PMV slightly shorter than MV. Mesoscutum width 0.24X length, scutellum medially 0.6X mesoscutum. Forewing (Fig. 4) with distinct arrangement of setae in costal cell, basal one fourth of wing almost without any setae; stigma moderately capitate; a distinct hair line present. Relative lengths SMV 5.05, MV 2.9, PMV 2.6, STV 1.7.

Gaster elongate ovate and non collapsing.

### Male

Unknown.

### Host

Pods of *Crotalaria mucronata* Desv.

### Holotype

One female, India: Bangalore, Hebbal, Veterinary college campus, 25.viii.2006, Ankita Gupta, ex: pods of *Crotalaria mucronata* Desv. Deposited in Project Directorate of Biological Control, Bangalore, India. Registration number is PTED1.

### Paratypes

Two females, same data as holotype. One deposited in Project Directorate of Biological Control, Bangalore, India. Registration number is PTED2. Other one will be deposited in National Pusa Collections, Indian Agricultural Research Institute, New Delhi, India. Registration number not yet received.

### Remarks

This new species is similar to *D. acutus* (Thompson) in having anterior margin of clypeus weakly bidentate but differs from it in having: (1) Antennae with pedicel shorter than F1. (2) PMV is a little shorter than MV. (3) Gaster highly metallic, noncollapsing, long and ovate; 0.5X as long as head plus mesosoma combined. Whereas in *D. acutus* pedicel is as long as F1; fore wing with PMV as long as MV; gaster short, 0.7X as long as head plus mesosoma combined. *D. crotalariae* is similar to *D. colemani* in having pedicel little shorter than F1 and with a long gaster, but differs in having anteroir margin of clypeus weakly bidentate; gaster shorter than head and mesosoma combined. In *D. colemani* the anterior margin of clypeus is slightly

projecting and not bidentate; PMV 0.8X as long as MV; and gaster is dorsally slightly collapsing, subequal to head and mesosoma combined. It also differs from *D. colemani* in not having bluish black body; pedicel plus flagellum length not equal to head width and clava not as long as two preceding segments combined.

The new species is similar to *D. maculatus* in having scape and pedicel yellowish brown in colour, anelli and clava brownish; similar brown bands on junction of funicular segments and coxae being concolorous. It differs from *D. maculatus* in not having metallic blue body; PMV not as long as nor slightly longer than MV and in not having a cordiform gaster.

## Etymology

This species is named after its host plant, *Crotalaria mucronata* Desv.

### REVISED KEY TO FEMALES OF *DINARMUS* SPECIES OF INDIA AND ADJACENT COUNTRIES

1. Anterior margin of clypeus with two sharp teeth; forewing with discal pubescence very sparse, almost indistinct; stigma strongly capitate; costal cell enlarged in males; POL 2X OOL; propodeum with nucha short.......... *altifrons* (Walker)

- Anterior margin of clypeus almost straight, shallowly emarginate or weakly bidentate; forewing with discal pubescence not reduced as above; stigma normal or moderately capitate; costal cell not enlarged as above; POL less than 2X OOL; propodeum with nucha moderately or distinctly projecting ................. 2

2. Forewing with PMV distinctly shorter than MV (0.6X) and only as long as STV; discal pubescence very short and less distinct; POL only slightly longer than OOL (6:5)......................................... *vagabundus* (Timberlake)

- PMV as long as, little longer or shorter than MV but distinctly longer than STV; discal pubescence distinct; POL distinctly longer than OOL ................. 3

3. Anelli transverse .............................................. 4

- Third anellus distinctly longer than second and as long as first and second combined.......................................................... 6

4. Anterior margin of clypeus slightly projecting, not bidentate; pedicel little shorter than F1; PMV 0.8X as long as MV; gaster long, dorsally slightly collapsing, subequal to head and mesosoma combined............... *colemani* (Crawford)

- Anterior margin of clypeus weakly bidentate ............................. 5

5. Antennae with pedicel as long as F1; fore wing with PMV as long as MV; gaster short, 0.7X as long as head plus mesosoma combined ...... *acutus* (Thompson)

- Antennae with pedicel shorter than F1; fore wing with PMV little shorter than MV; gaster highly metallic, long and ovate; 0.5X as long as head plus mesosoma combined ......................................... *crotalariae* sp.nov.

6. Anterior margin of clypeus almost straight, not projecting; PMV as long as or slightly longer than MV; antennae slender with scape reaching middle of median ocellus, yellowish brown except anelli and clava brown; similar brown bands on junction of funicular segments; POL subequal to OOL; gaster highly cordiform ........................................................ *maculatus* (Masi)
- Anterior margin of clypeus shallowly emarginate, slightly projecting; PMV 1.3X OOL; antennae not slender, scape hardly reaching median ocellus, uniformly yellowish brown or brown without brown rings on funicular segments; POL 1.3X OOL; gaster not cordiform .............................. *basalis* ( Rondani)

**Abbreviations**

FI – First funicular segment, MV – Marginal vein, PMV – Postmarginal vein, SMV – Submarginal vein, OOL – Ocellocular distance, POL – Post ocellar distance, STV – Stigmal vein.

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**Checklist of the species of *Dinarmus* spp. of India and adjacent countries**

*maculatus* - *Sphaerakis maculatus* (Masi, 1924): 157, Burma. Lectotype female (MCSN).

*altifrons* - *Pteromalus altifrons* Walker, 1862 :388

*D. stringifrons* (Waterston), 1922:32. Male India (Dehradun) (BMNH) syn. by Rasplus, 1989: 149.

*basalis* - *Entedon basalis* Rondani, 1877: 174. Male, Italy (Lectotype, Florence Museum).

*vagabundus* - *Bruchobius vagabundus* Timberlake, 1926:305. Female. USA (Hawaii), Honolulu (BPBM).

*acutus* - *Dimachus (Dinarmus acutus)* Thomson, 1878:56. Female, Boheman (UZIL).

*colemani* - *Bruchobius colemani* Crawford, 1913: 250. Female, India (Bangalore) (USNM).

*crotalariae* sp. nov. - *Dinarmus crotalariae* Gupta. Female, India (New Delhi) (NPC, IARI).

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# Diversity, trophic relationships and biomonitoring potential of Ephemeroptera, Plecoptera and Trichoptera communities in streams of southern Eastern Ghats

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ABSTRACT: A survey of Ephemeroptera, Plecoptera and Trichoptera (EPT) occupying streams in three hills of south portion of Eastern Ghats was conducted between October 2004 and May 2005. Three sites were selected on each stream and visited monthly throughout the sampling period. A total of 2,226 individuals belonging to 14 genera and 10 families of the three taxa were collected. Diversity indices showed higher values in stream of Sirumalai hill. High similarity was observed between Karanthamalai and Sirumalai and low similarity between Alagarmalai and Sirumalai. Collectors were predominant than other functional feeding groups. Sirumalai stream scored high BMWP values indicating good water quality.


KEYWORDS: species richness, water quality assessment, Eastern Ghats, Ephemeroptera, Plecoptera, Trichoptera

## INTRODUCTION

A large number of major and minor rivers flow through the Eastern Ghats, which is an assemblage of a series of broken hills spreading over the states Orissa, Andhra Pradesh and Tamil Nadu in India. Several investigations on the aquatic insects of streams of Western Ghats have already been reported (Anbalagan *et al.*, 2004; Subramanian *et al.*, 2005; Anbalagan and Dinakaran, 2006; Dinakaran and Anbalagan, 2007). But no attempt has so far been made to study the fauna of these rivers of Eastern Ghats. The objective of the present study was to evaluate the species richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) community in hill streams of Eastern Ghats, Tamil Nadu.

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## MATERIALS AND METHODS

The Eastern Ghats are located between latitude 10° and 22° N and longitude 76° 50′ and 86° 30′ E. The Ghats cover an area of about 75,000 km$^2$, with an average width of 200 km in the North and 100 km in the South. They extend over a length of 1750 km. The region falls under tropical monsoon climate receiving rainfall from both southwest and northeast monsoon. Vegetation varies considerably with altitude and shows a distinct zonation of forest types. As a whole, the vegetation is typically deciduous type and scrub jungle in most places. For this investigation, streams from three hills namely, Karanthamalai (10° 17′ N and 78° 14′ E), Alagarmalai (10° 04′ N and 78° 12′ E) and Sirumalai (9° 28′ N and 77° 22′ E) were chosen.

The study was conducted between October 2004 and May 2005. Three sites were selected in each stream and EPT taxa were quantitatively sampled every month using a 1m wide Kick-net (mesh size-1 mm). Riffle/run areas of stream were selected for sampling since such area is suitable for Kick-net sampling. EPT taxa were picked from the net surface and immediately preserved in 70% ethyl alcohol. Three samples were collected from each stream as three replicates in data. Genera/species of EPT taxa were identified in the laboratory. Mouth-part morphology and gut content were also examined for functional feeding group analysis (Cummins and Wilzbach, 1985; Dudgeon, 1999). Physico-chemical parameters were assessed following methods prescribed by American Public Health Association (1995).

Alpha diversity indices of Shannon-Weiner index and Simpson index were worked out. The Shannon index and Simpson index of diversity were calculated (Ludwig and Reynolds, 1988). Similarities in taxonomic composition were quantified using Jaccard's index (Sneath and Sokal, 1973) based on a presence-absence matrix for the insect fauna of each stream. A Bray-Curtis cluster analysis was performed using a flexible method ($\beta = -0.25$) using PAST Program (version 1.42). BMWP (Biological Monitoring Working Party) score was calculated by the procedure: list the families present, ascribe the score for each family, and then add the scores together to arrive at a site score. Score value for individual family reflects its pollution tolerance based on current knowledge of distribution and abundance (Armitage *et al.*, 1983).

## RESULTS

A total of 2226 individuals of EPT complex belonging to 14 genera of 10 families were collected (Table 1). Diversity and abundance of EPT taxa were highest during October in Karanthamalai and Sirumalai streams and February in Alagarmalai stream. The lowest diversity of EPT taxa was observed in May in all the streams (Table 2).

Among alpha diversity indices, Shannon-Weiner index and Simpson's index were calculated for all the sampling stations. Shannon-Weiner index and Simpson's index showed the higher values (2.232; 0.8698) and species richness was higher in Sirumalai stream than Karanthamalai and Alagarmalai streams. Similarity matrix showed that there was a higher similarity in EPT richness between Sirumalai and Alagarmalai and low between Karanthamalai and Sirumalai. The Similarities between three hill streams among EPT taxa are depicted as dendrogram (Fig. 1).

TABLE 1. EPT taxa in the streams originating from three hills of Eastern Ghats in Tamil Nadu

| Order | Family | Genus/species | Presence/absence | | |
|---|---|---|---|---|---|
| | | | Karantha-malai | Alagar-malai | Sirumalai Sirumalai |
| Ephemeroptera | Baetidae | *Baetis* sp. | + | + | + |
| | Heptageniidae | *Cinygmina kumbakkariensis* | – | – | + |
| | | *Thalerosphyrus flowersi* | + | – | + |
| | Leptophlebiidae | *Choroterpes alagarensis* | + | + | + |
| | Teloganodidae | *Teloganodes* sp. | + | + | + |
| | Caenidae | *Caenis* sp. | – | – | + |
| Plecoptera | Perlidae | *Neoperla biseriata* | + | – | + |
| Trichoptera | Hydropsychidae | *Potamyia* sp. | + | – | + |
| | | *Parapsyche* sp. | – | – | + |
| | | *Hydropsyche* sp. | + | + | + |
| | | *Cheumatopsyche* sp. | – | – | + |
| | Polycentropodidae | *Polycentropus* sp. | – | – | + |
| | Calamoceratidae | *Anisocentropus* | – | – | + |
| | Lepidostomatidae | *Goerodes* sp. | – | + | + |

+ present , – absent

TABLE 2. Abundance and number of EPT taxa in three streams of Eastern Ghats during October, February and May of 2004–2005

| Stream | October | | February | | May | |
|---|---|---|---|---|---|---|
| | Abun -dance | No. of taxa | Abun -dance | No. of taxa | Abun -dance | No. of taxa |
| Karanthamalai | 301 | 7 | 255 | 7 | 154 | 6 |
| Alagarmalai | 110 | 5 | 125 | 5 | 54 | 5 |
| Sirumalai | 927 | 13 | 270 | 9 | 30 | 5 |

Collectors was the predominant group among the functional feeding groups in all the streams sampled. In Sirumalai stream collectors dominated (55%) followed by filter-feeders (18%), predators (14%), scrapers (9%) and shredders (4%). In Karanthamalai collectors dominated (45%) followed by predators (26%), filter-feeders (23%), scrapers (4%) and shredders (2%). In Alagarmalai, collectors (67%) were predominant followed by shredders (24%); while scrapers (6%) and predators (3%) were the less occupied group. Filter-feeders were conspicuous by their absence. In

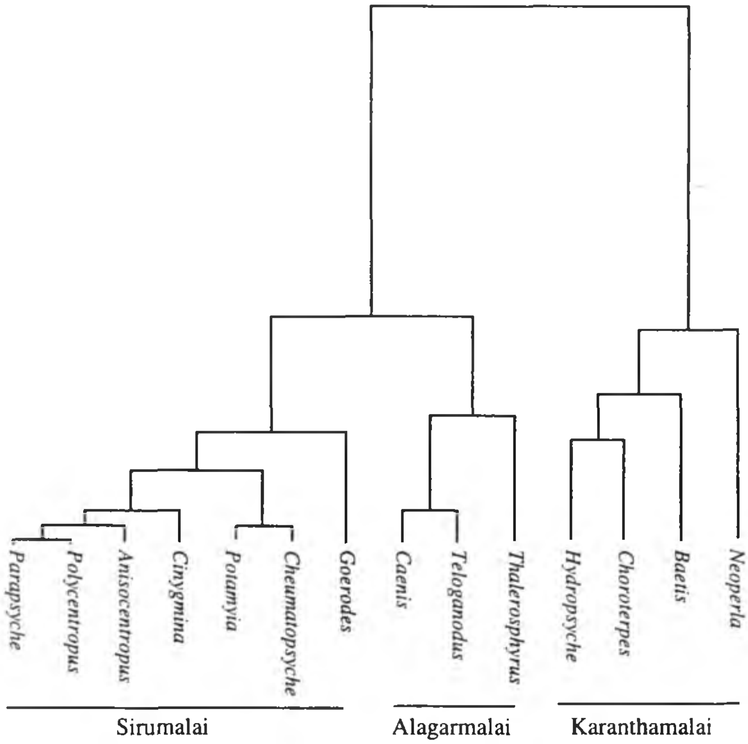


FIGURE 1. Dendrogram showing the similarity matrix for genera in streams of three hills

TABLE 3. Relative abundance of functional feeding groups in the streams of three hills of Eastern Ghats

| | Percentage of different feeders | | |
|---|---|---|---|
| Feeding groups | Karanthamalai | Alagarmalai | Sirumalai |
| Predator | 26.3 | 2.9 | 14.0 |
| Scraper | 4.2 | 6.2 | 9.2 |
| Filter-feeder | 22.8 | 0 | 18.1 |
| Collector | 44.6 | 67.3 | 55.2 |
| Shredder | 1.9 | 23.6 | 3.6 |
| Total | 100 | 100 | 100 |

terms of abundance of functional feeding groups, collectors were most abundant (Table 3).

Assemblages of EPT taxa were compared between sampling sites. The results clearly explained the variations existing between the sampling stations. BMWP

TABLE 4. BMWP scores for families of EPT taxa in the streams of three hills of Eastern Ghats

| Family | Karanthamalai | Alagarmalai | Sirumalai |
|---|---|---|---|
| Leptophlebiidae | 10 | **10** | **10** |
| Heptageniidae | 0 | **10** | **10** |
| Baetidae | 4 | **4** | **4** |
| Teloganodidae | 10 | **10** | **10** |
| Caenidae | 0 | **0** | **7** |
| Perlidae | 10 | **0** | **10** |
| Polycentropodidae | 10 | **10** | **10** |
| Hydropsychidae | 0 | **0** | **5** |
| Lepidostomatidae | 0 | **5** | **10** |
| Calamoceratidae | 0 | **0** | **10** |
| Total | 44 | 49 | 86 |

analysis showed the prisitnity of streams. Sirumalai secured greater score (86) than Alagarmalai (49) and Karanthamalai (44) (Table 4).

## DISCUSSION

Diversity analyses indicated that higher diversity values for EPT taxa were observed in stream of Siurmalai hills during October. Many factors were probably responsible for this, especially influence of monsoon, where southern Eastern Ghats receives maximum rainfall during Northeast monsoon (October). Lewis and Harrel (1978) found higher species diversity values during the periods of high discharge, which was attributed to many taxa being carried into the main stream from tributaries. Another factor related to discharge is the amount of plant debris washed into the river from either runoff or increased water levels and they provided habitat and nutrients for aquatic insect community.

Invariably all the sampling sites were dominated by collectors followed by filter feeders, predators, scrapers and shredders. The functional feeding group analyses agreed with the River Continuum Concept (Vannote *et al.*, 1980). Dominance of collector species might be due to fine particulate organic matter from upstream reaches and decomposing activities by microbial communities inhabiting the sampling sites. Previous studies suggest that consumers selectively assimilate a small fraction of natural detritus and that the rest is in fact passed rather quickly through the gut (Schindler, 1968; Bell and Ward, 1970; Hargrave, 1970).

Low BMWP scores from Karanthamalai may be due to anthropogenic disturbances by tourists and pilgrims. Water quality at this site should be monitored closely in coming years. Under natural conditions EPT diversity is directly correlated with habitat variety and therefore modified 'Species-Deficit-Concept' (Kothe, 1962) should effectively reflect the state of overall ecological integrity for a defined sampling area. The greatest impediment for practical application is the insufficient knowledge of the

species inventory for different sampling stations due to unknown distribution models and, subsequently, data incomparability. The outstanding importance of reliable faunistic baseline data and their value for future conservation projects is amply documented from long-term studies (Landa *et al.*, 1997; Sartori and Landolt, 1998). In Eastern Ghats at least, these difficulties must be overcome with regard to EPT community.

## ACKNOWLEDGEMENTS

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# A report on two new species and three new records of Drosophilidae from Kumaon region, Uttaranchal, India

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ABSTRACT: A taxonomic account of five species belonging to the genus *Leucophenga*, *Microdrosophila*, *Dichaetophora* and *Lordiphosa* are given. *Leucophenga trispina* and *Microdrosophila* (*Microdrosophila*) *bamanpuriensis* are described as new species while *Dichaetophora acutissima*, *Leucophenga argentata* and *Lordiphosa tripartita* are recorded for the first time from India.


KEYWORDS: Drosophilidae, Diptera, Kumaon, India, new records and new species

A number of drosophilid species has been recorded from the Kumaon region which includes six border districts of the state Uttaranchal, *viz*., Nainital, Almora, Pithoragarh, Bageshwar, Champawat and Udham Singh Nagar (Singh and Negi, 1989; Singh and Dash, 1993; Singh *et al*., 2004; Fartyal *et al*., 2005). This area is characterized by dense evergreen coniferous forest with medium to very steep slopes and extremely moist condition due to heavy rainfall. Results of a drosophilid survey undertaken in the still unexplored region of Kumaon are described in this paper.

The collections were largely made by net sweeping over wild vegetation and by trap bait method. The flies were preserved in 70% alcohol and observed under the microscope. In this paper we have adopted the revised classification and terminology by Grimaldi (1990), Zhang and Toda (1992) respectively. The specimens are deposited in the Department of Zoology, Kumaon University, Nainital.

## Genus *Leucophenga* Mik

*Leucophenga* Mik, 1886. Wiener Ent, Zeitung. 5:317. Type species: *Drosophila maculata* Dufour, Europe.

In genus *Leucophenga* lower rays of arista as long as upper ones; frons often narrow; eye very large, vertical; gena very narrow, apical scutellars divergent; excessive small

scutellars absent; thornlike spines below costa present; costa reaching apex of $R_{4+5}$; male often with some silvery sheen on frons, scutum and abdomen (after Bächli, 1998). Proclinate and anterior reclinate orbital setae very close together, separated by distance less than 1/2 of that between anterior reclinate and posterior reclinate; gonopod fused with each other, forming somewhat triangular plate, anteroventrally with apically curved median rod; surstylus squared, flat, broad (after Grimaldi, 1990).

***Leucophenga trispina*** **sp. nov.**

Average length of the body: 3.7 mm ($n = 1$, ♂)

*Head (♂):* Arista with 7 upper and 3 lower branches in addition to terminal bifurcation. Antenna with pedicel brown and flagellomere grey. Frons including ocellar triangle light brown. Palpus dark brown. Orbitals in the ratio of 6:4:12. Vibrissa thick and prominent and subvibrissa smaller than vibrissa. Gena brown and greatest width of gena 0.2 the greatest diameter of eye. Eyes are red.

*Thorax (♂):* Acrostichal hair in 12 regular rows in front of dorsocentral bristles. Mesonotum brown. Scutum brown. Ratio between anterior and posterior dorsocentral about half the distance between two anterior dorsocentrals. Sterno-index 0.8. Legs light brown. Preapical bristles present on mid and hind tibiae; apical bristles present on mid tibiae.

*Wings (♂) (Fig. 1C):* Cross veins r-m and dm-cu clear. $C_1$ setulae two, unequal in size. Anterior and posterior cross-veins fuscous with black patches. Black patches near $R_1$ and $R_{2+3}$, $R_{4+5}$ without black patch. $C_3$ fringe 1.0. Average wing vein indices: C-index 1.66; 4V-index 2.04; 4C-index 1.56; 5x-index 0.93. Halteres pale yellow.

*Abdomen (♂):* Abdomen yellow. Ist abdominal tergite with two lateral black patches, IInd tergite with narrow black band, IIIrd, IVth, Vth and VIth abdominal tergites with black band and white patches.

*Periphallic organs (Fig. 1B):* Epandrium broad above and below, pubescent with about 11-12 large setulae. Surstylus quadrate, fused to epandrium, pubescent and with about 19-20 small setulae and 4 marginal sensilla.

*Phallic organs (Fig. 1A):* Aedeagus large, swollen at the tip with a number of small sensilla. Gonopod large, black, cylindrical and pointed at the tip. Posterior gonophyses absent. Hypandrium round with 3 small black setulae. Hypandrial apodeme almost quadrate. Aedeagal apodeme larger than hypandrial apodeme.

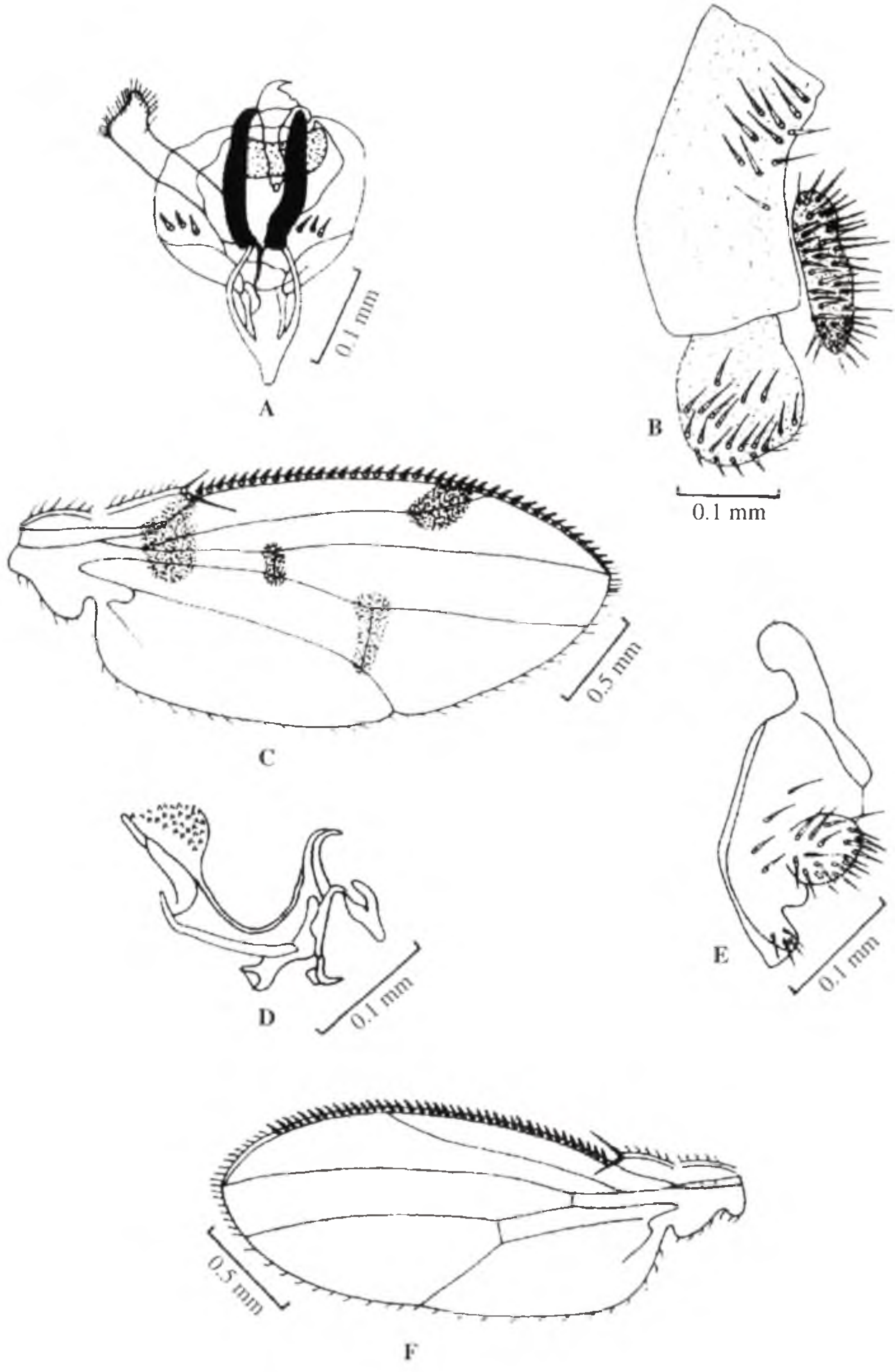


FIGURE 1. A–C: *Leucophenga trispina*, A – phallic organs; B – periphallic organs; C – wing. D–F: *Microdrosophila bamanpuriensis*, D – phallic organs; E – periphallic organs; F – wing.

*Holotype male*

India: Uttaranchal, Kumaon, Bageshwar district, Kausani, 01 ♂, 18. VIII. 2003. Coll. Upadhyay and Singh; by net sweeping; deposited in the Department of Zoology, Kumaon University, Nainital.

*Distribution*

Kausani (Kumaon), India.

*Relationship*

This species is a member of the genus *Leucophenga* where it resembles *Leucophenga digmasoma* (Lin and Wheeler, 1972) but distinctly differs from it in the structure of periphallic and phallic organs.

**Genus *Microdrosophila* Malloch**

*Microdrosophila* Malloch, 1921, p. 312. Type-species *Drosophila quadrata* Sturtevant, 1916, by original designation; type locality Alabama, U.S.A.

*Oxystyloptera* Duda, 1924a, p. 192. Type-species *Drosophila tectifrons* de Meijere, 1914, by subsequent designation (Burla 1954b); type locality Java. (Wheeler and Takada, 1964).

*Incisurifrons* Duda, 1924c, p. 248 (as subgenus of *Drosophila*). Type-species *Drosophila congesta* Zetterstedt, 1847, by monotypy; type locality Scandinavia. (Sturtevant, 1921).

*Hopkinsomyia* Malloch, 1934, p. 289. Type-species *H. convergens* Malloch, 1934, by original designation; type locality Samoa. (Harrison, 1954).

Breadth of front considerably greater than length; front with more or less distinct oblique line or band on each side between ocellar triangle and periorbit to anterior margin; anterior reclinate orbital bristle small, minute or indistinguishable from adjacent microchaetae, other cephalic bristles typically large; vibrissa single, typically very large; mesonotum typically with 2 pairs of large dorsocentral bristles, anterior pair situated close to transverse suture; prescutellar bristles absent; anterior sternopleural bristle fine; middle sternopleural very small; costal index typically low; 3rd costal section with extensive fringe of heavy bristles; egg guide of female typically weakly developed.

***Microdrosophila* (*Microdrosophila*) *bamanpuriensis* sp. nov.**

Average length of the body: 1.7 mm ($n = 1$, ♂)

*Head (♂):* Arista with 7 upper and 3 lower branches in addition to terminal bifurcation. Antenna with pedicel and flagellomere light brown. Frons including ocellar triangle faded black. Orbitals in the ratio of 6:5:7. Palpus grey and facial carina pale yellow. Vibrissa prominent and subvibrissal setae minute. Gena yellow, greatest width of gena 0.1 the greatest diameter of eye. Eyes yellow.

*Thorax (♂):* Mesonotum shiny tan anteriorly, a little darker posteriorly. Acrostichal hair in 8 rows in front of dorsocentral bristles, 6 rows between dorsocentrals. The ratio between anterior and posterior dorsocentrals 0.6. Scutum yellowish brown and scutellum brown. Anterior Scutellar bristles 0.6 length of posterior scutellars. Sterno-index 0.6. Legs light brown; preapical bristles present on all tibiae; strong apical bristle on 2nd tibia only.

*Wings (♂) (Fig. 1F):* Cross veins r-m and dm-cu clear. $C_1$ setulae two, unequal in size. $C_3$ fringe 0.44. Average wing vein indices: C-index 1.44; 4V-index 2.77; 4C-index 1.77; 5x –index 3.0. Halteres pale yellow.

*Abdomen (♂):* Entirely blackish brown, slightly shining.

*Periphallic organs, (Fig. 1E):* Epandrium narrow anteriorly and posteriorly and broad in the middle with 4 setulae in the middle and 4 at the posterior side. Cercus small, oval and fused to epandrium with 16-17 large setulae.

*Phallic organs (Fig. 1D):* Aedeagus small and cup shaped with a number of small spines. Gonopod small, flattened and narrow at the tip. Posterior gonapophyses absent. Hypandrium curved and pointed at the tip. Hypandrial apodeme quadrangular. Aedeagal apodeme small, equal to hypandrial apodeme.

*Holotype male*

India: Uttaranchal, Kumaon, Almora district, Dwarahat, 01♂, 21. IX. 2003. Coll. Upadhyay and Singh; by net sweeping; deposited in the Department of Zoology, Kumaon University, Nainital.

*Distribution*

Dwarahat (Kumaon), India.

*Relationship*

This species is a member of the subgenus *Microdrosophila* of the genus *Microdrosophila* where it resembles *Microdrosophila curvula* (Zhang, 1989) but distinctly differs from it in the structure of periphallic and phallic organs. The species name refers to the place from where it was collected.

**Genus *Dichaetophora* Duda (New record)**

*Dichaetophora* Duda, 1940: (also as *Dichaetophila*, error). Type species: *Drosophila aberrans* Lamb, 1914.

*Nesiodrosophila* Wheeler and Takada, 1964: 238. Type species: *Nesiodrosophila lindae* Wheeler and Takada, 1964. Syn.n.

*Dichaetophora* was established as a subgenus of *Drosophila* Fallén by Duda (1940), based on the single species, *Drosophila aberrans* Lamb, from the Seychelles. Grimaldi (1990) concluded it as an independent genus. Further cladistic analysis of genus *Dichaetophora* was studied by Hu and Toda (2002).

The cibarium only slightly protruded at anterolateral corners; the oviscapt with apical ovisensillum robust and the largest, distinguishable from the others (also seen as a synapomorphy, ap. 213 of Grimaldi (1990), in some Drosophilinae genera not included in the present study, such as *Jeannelopsis* Seguy, *Sphaerogastrella* Duda, *Mulgravea* Bock and *Liodrosophila* Duda); the basal lobe of palpus without setulae; the hypopharyngeal apodeme expanded anteriorly; the labellum with less than six pseudotracheae; the ocellar setae outside triangle made by ocelli (except for *L. harpophallata*).

### *Dichaetophora acutissima* Okada (New record)

*acutissima* Okada, -Formosa, Nepal, Ryukyu Islands (Amami); Japan. 1956. 139 (Japan).

Average length of the body: 8.7 mm ($n = 1$, ♂)

*Head (♂):* Arista with 5 upper and 2 lower branches with terminal fork. Antenna with pedicel and flagellomere light brown. Frons including ocellar triangle light brown. Palpus light brown. Orbitals in the ratio of 6:5:10. Facial carina brown. Vibrissa prominent and subvibrissal setae minute. Gena yellow and maximum width of it is 0.1 the diameter of eye. Eyes are brown.

*Thorax (♂):* Acrostichal hair in 8 regular rows. Scutum and scutellum brown. Anterior dorsocentrals convergent and posterior dorsocentrals convex. Basal scutellar opposite to each other and apical scutellar setae crossing each other. Sterno-index 0.66. Legs yellowish brown. Preapicals and apicals present on all tibia.

*Wings (♂) (Fig. 2C):* Cross veins r-m and dm-cu clear. $C_1$ setulae two, unequal in size. $C_3$ fringe 0.66. Average wing vein indices: C-index 3.33; 4V-index 1.89; 4C-index 0.78; 5x–index 2.5. Haltere stem pale yellow and knob light brown.

*Abdomen:* Abdominal tergites uniformly brownish black.

*Periphallic organs (Fig. 2B):* Epandrium broad anteriorly and narrow posteriorly, completely pubescent, with about 5 small setae on the anterior side and 2 small and 5 long setae on the posterior side. Surstylus oval, attached to epandrium, pubescent with about 20-21 small setae. Cercus round, separated from epandrium, pubescent and with about 22 large setae.

*Phallic organs (Fig. 2A):* Aedeagus club shaped, anteriorly bilobed and serrated. Gonopod small leaf like and attached to the base of aedeagus. Parameres small leaf like

with a small apical sensilla. Hypandrium broad above and narrow below. Hypandrial apodeme triangular. Aedeagal apodeme short, equal to hypandrial apodeme.

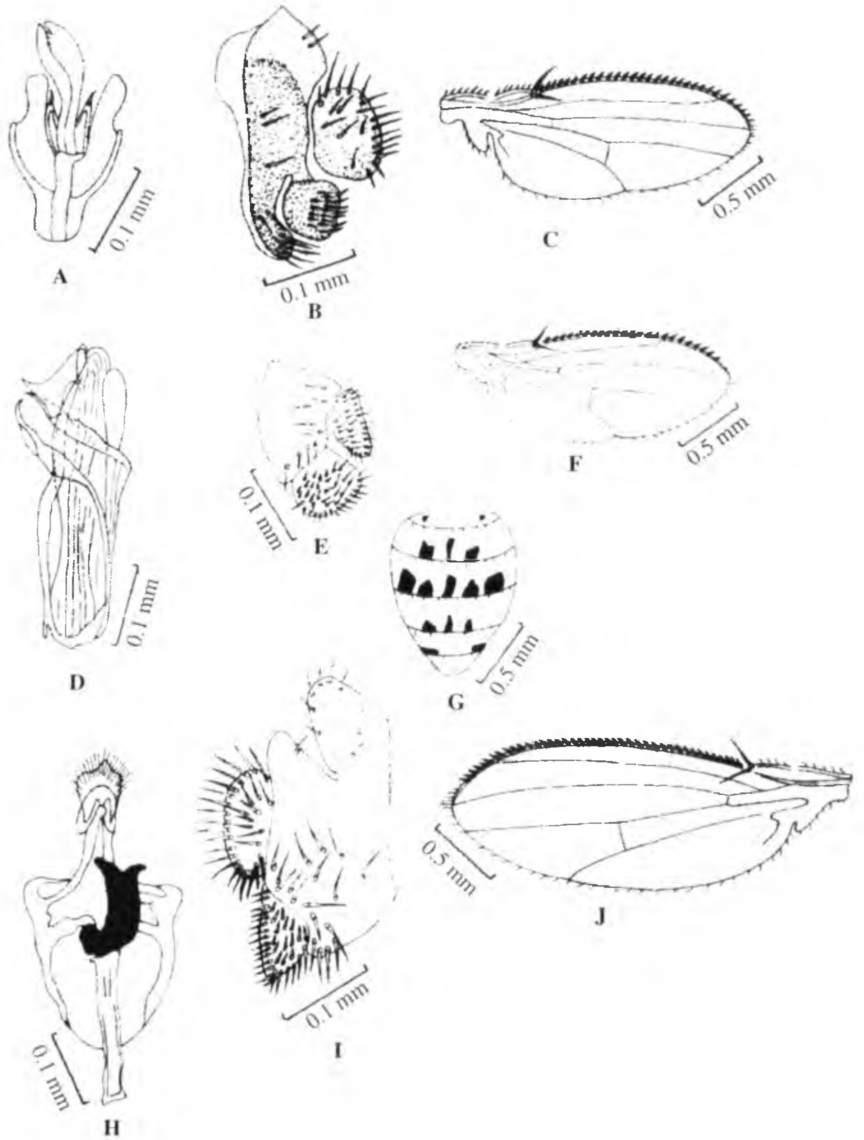


FIGURE 2. A–C: *Dichaetophora acutissima*, A – phallic organs; B – periphallic organs; C – wing. D–G: *Leucophenga argentata*, D – phallic organs; E – periphallic organs; F – wing; G – abdomen (♂). H–J: *Lordiphosa tripartita*, H – phallic organs; I – periphallic organs; J – wing.

*Specimens examined*

India, Uttaranchal, Kumaon, Bageshwar district, Kausani, 01 ♂, 19. VIII. 2003. Coll. Upadhyay and Singh.

*Distribution*

Formosa, Nepal, Ryukyu Islands (Amami), Japan, India (Kausani, Almora district).

***Leucophenga argentata* de Meijere (New record)**

*Drosophila argentata* de Meijere, 1914, p. 258. (Holotype in Amsterdam; type locality Java).
*Leucophenga halteropunctata* Duda, 1924a, p. 188; 1924b, p. 239. (Holotype in Berlin; type locality Taiwan). [Female of *argentata*: Wheeler and Takada, 1964; Lin and Wheeler, 1972.]
*Leucophenga argentata* species group: Bächli, 1971: 106.

Average length of the body: 2.5 mm ($n = 3$, ♂)

*Head (♂):* Arista with 8 upper and 2 lower branches in addition to terminal furcation. Antenna with pedicel and flagellomere yellow. Frons including ocellar triangle pale yellow.Palpus pale yellow. Orbitals in the ratio of 3:3. Facial carina dark yellow. Vibrissa prominent and subvibrissal setae minute. Gena yellow and greatest width of gena 0.2 the greatest diameter of eye. Eyes light brown.

*Thorax (♂):* Acrostichal hair in 10 regular rows. Scutum dark yellow. Scutellum with very small black spots at the bases of anterior scutellar bristles. Sterno-index about 0.8. Anterior scutellars divergent, posterior slightly nearer to each other than to anterior. Legs light brown. Preapicals on mid and hind legs; apicals prominent on mid leg.

*Wings (♂) (Fig. 2F):* Cross veins r-m and dm-cu clear. $C_1$ setulae two, unequal in size. $C_3$ fringe 0.26. Average wing vein indices: C-index 1.8; 4V-index 3.16; 4C-index 1.9; 5x-index 1.9. Halteres white, knob black.

*Abdomen (♂) (Fig. 2G):* Abdomen light yellow. Ist tergite with two small lateral black spots; IInd tergite with three small black spots in postero ventral side; IIIrd tergite with five black spots, out of which two large black spots on postero lateral side; IVth tergite with three small black spots on postero-ventral side; Vth tergite with two small black spots on lateral side; VIth tergite pale yellow.

*Periphallic organs (Fig. 2E):* Epandrium broad, entirely pubescent, with about nine large setae scattered on posterodorsal margin to ventral portion. Surstylus broader than long, ovoid, pubescent, with about 35–40 setae. Cercus large, separated from epandrium, entirely pubescent, with about 30–35 setae.

*Phallic organs (Fig. 2D):* Aedeagus long and bifid. Paramere long and leaf like. Gonopod absent. Hypandrium arched and pointed at the tip. Hypandrial apodeme triangular. Aedeagal apodeme absent.

*Specimens examined*

India: Uttaranchal, Kumaon, Almora district, Dwarahat, 01 ♂, 21. VIII. 2003, Dunagiri, 01 ♂, 22. VII. 2003: Pithoragarh district, Gangolihat, 01 ♂, 8. VIII. 2004. Coll. Upadhyay and Singh.

*Distribution*

China (Taiwan), Philippines, Micronesia, Nepal, Okinawa and New Guinea, Japan (Ryukyu Islands), Thailand, Singapore, Sri Lanka, Indonesia (Java), Australia, India (Dwarahat, Dunagiri, Gangolihat, Uttaranchal).

**Genus *Lordiphosa* Basden**

*Lordiphosa* Basden, 1961, Beitr. Ent., 11: 186.

Acrostichal setulae in 4–6 rows; ventral receptacle long and loosely looped; eggs with two short filaments; parameres often hairy; aedeagus with dense microsetae at apex.

***Lordiphosa tripartita* Okada (New record)**

*Lordiphosa tripartita* Okada, 1966, Bull. Br. Mus. nat. Hist. (Ent.) Suppl. 6:78 (♂♀). Type loc: Sangus, Taplejung District, Nepal.

Average length of the body: 2.1 mm ($n = 1$, ♂)

*Head (♂):* Arista with 4 upper and 2 lower branches in addition to terminal bifurcation. Antenna with pedicel and flagellomere light brown. Frons including ocellar triangle brown. Palpus yellow. Orbitals in the ratio of 11:7:14. Facial carina light brown. Clypeus dark brown. Vibrissa long and subvibrissa half of the size of vibrissa . Gena light brown and greatest width of gena 0.2 the greatest diameter of eye. Eyes are red.

*Thorax (♂):* Acrostichal hair in 6 rows. Scutum and scutellum light brown. Anterior dorsocentrals nearly half as long as posterior; distance between anterior and posterior dorsocentral about half the distance between two anterior dorsocentrals; anterior scutellars divergent, longer than posteriors. Sterno-index about 0.5. Legs yellow, preapicals on all three tibiae, apicals on second tibiae only.

*Abdomen (♂):* Abdominal tergites yellowish brown.

*Wings (♂) (Fig. 2J):* Cross veins r-m and dm-cu clear. $C_1$ setulae two, equal in size. $C_3$ fringe 0.5. Average wing vein indices: C-index 3.5; 4V-index 1.54; 4C-index 0.64; 5x–index 1.87. Haltere yellow.

*Periphallic organs (Fig. 2I):* Epandrium broad above and narrow below, bare with about 9 setulae at the anterior margin and 17-18 at the posterior side. Surstylus small, fused to epandrium with about 16-18 small marginal setulae, 17-18 small dorsal setulae and 6 large setulae at the posterior margin. Cercus small, oval, fused to epandrium with about 22 large setulae and 7 small black setulae at the posterior margin.

*Phallic organs (Fig. 2H):* Aedeagus large and club shaped with a number of sensilla at the tip. Gonopod S-shaped, black and pointed at the tip. Hypandrium rounded. Hypandrial apodeme triangular. Aedeagal apodeme larger than hypandrial apodeme.

*Specimens examined*

India: Uttaranchal, Kumaon, Almora district, Dunagiri, 01 ♂, 08. VIII. 2003. Coll. Upadhyay and Singh.

*Distribution*

Nepal, Dunagiri (Kumaon), India.

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# Development of the rice leaf folder, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) on different diets and *in vitro* assay of *Bacillus thuringiensis*

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ABSTRACT: Development of the rice leaf folder, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) was tested on different diets to explore the scope of excluding rice plant component and select a medium for normal development of the insect to conduct *in vitro* assay of *Bacillus thuringiensis* (Bt). First instar larvae of the rice leaf folder completed its life cycle on the Leaf Folder, *Drosophila*, *D. melanogaster* and Fruit Fly diets but survived up to fourth instar only on the Stem Borer, Leaf and Plant Hopper and *Heliothis* diets. Optimum adult emergence was about 95–99% on the rice plant, *Drosophila* and Fruit Fly diets; about 65% on the Leaf Folder diet but only about 35% on the *D. melanogaster* diet. Development of the insect was optimum at 30 °C. After 12 h starvation, the third-fifth instar larvae that developed on artificial diets had lower growth index than those developed on the rice plants. The two commercial diets i.e. the Fruit Fly and *Drosophila* diets (Himedia product no. ID001 and ID002, respectively) were found suitable for development of *C. medinalis*. The $LC_{50}$ of the indigenous and formulated *Bacillus thuringiensis* subspecies assayed by incorporation in the *Drosophila* and Fruit Fly diets ranged 6.11–44.10 × $10^3$ spore-crystals/ml medium. 

KEYWORDS: rice leaf folder, *Cnaphalocrocis medinalis*, diet, *Bacillus thuringiensis* assay

## INTRODUCTION

The rice leaf folder (LF), *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae), is a major pest of rice. To evolve effective non-chemical control of the insect, preliminary laboratory studies are essential. For laboratory experiments in Entomology, larvae are exclusively used as test organisms. Hence, for mass scale laboratory test,

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artificial media become essential. Media which may support development of *C. medinalis* comparable to that on rice plant would be preferrable because nutrition deficient media may truncate life cycle or cause higher mortality or produce physiologically unhealthy insects which may produce misleading bioassay results. The designated LF diet not only requires rice plant extract, insect mortality is also more and supports only about 37% adult emergence (Dakshyani *et al.*, 1988) which render it unsuitable for bioassay. The basic nutritional requirements of different insects being similar, the commercial Fruit Fly and Drosophila diets (Himedia product no. ID001 and ID002, respectively) (HiMedia, 2003); laboratory prepared *D. melanogaster, Heliothis,* Leaf and Plant Hopper diets which lack rice plant factor; and LF and Stem Borer diets which require rice plant factor (Dakshyani *et al.*, 1988; Koyama, 1988; Siddiqui and Dey, 2001) were assessed to determine their relative suitability for development of *C. medinalis*. The objectives of the investigation were selection of suitable media without rice plant component for complete and healthy development of *C. medinalis*, mass scale diet incorporation assay of virulence of *Bacillus thuringiensis* (Bt) to reduce time and labour and preliminary selection of potent Bt against *C. medinalis*.

## MATERIALS AND METHODS

Development of the leaf folder, *C. medinalis* larvae was monitored on the diets recommended for lepidopteran insects viz. Stem Borer (SB), *Heliothis* (H) and Leaf Folder (LF) (Kalode *et al.*, 1970; Nagarkatti and Satya, 1974; Dakshyani *et al.*, 1988); dipteran insects viz. *D. melanogaster* (DM), *Drosophila* (D), and Fruit Fly (FF) (Lewis, 1960; HiMedia, 2003) and the homopteran/orthopteran insect viz. Leaf and Plant Hoppers (LPH) (Koyama, 1988). Rice seedling (RS) variety TN1 also was included in treatments for comparison. Formaldehyde was omitted from the LF, H and SB diets. The D and DM media (10 ml in 100 ml flask) were autoclaved at 121 °C for 15 min and 40 mg/l tetracycline (filter sterile) was added (except for bioassay) prior to solidification. Other media were prepared by boiling with constant stirring, 40 mg/l tetracycline was added (except for bioassay) before solidification and 10 ml aliquots were distributed in 100 ml flasks. Open ends of the flasks were covered with insect proof netlon during experimentation.

The experiments were performed on potted rice (variety TN1) seedlings and on the diets contained in flasks maintained in an environmental chamber and a BOD incubator, respectively. They were monitored under 12 h alternating light and dark phases provided by six fluorescent tubes (3 ft., 30w), 85 ± 3% RH and 30 ± 0.1 °C temperature which are prevailing seasonal mean temperature (*Rabi*: late March and *Kharif*: mid September, about 25–32 °C) and humidity (85 ± 3% RH) for *C. medinalis* infestation under Cuttack conditions (Mishra *et al.*, 1999). Developmental time and colour of the larvae were recorded separately for first-fourth instar and fifth instar–moth stage for comparison of truncated life cycle at fourth instar stage on some diets. Field collected early first instar larvae (1d) of similar size, vigour (live wt. 0.62–0.64 mg), activity and presumably having similar natural endurance were used in this study to minimize the effects of artificial conditions during development of LF or assay

of Bt. The larvae were surface sterilized with 1.6% NaOCl and washed three times with sterilized distilled water. Twenty larvae were released on each of the potted rice seedlings (RS) and flasks containing different media. The insects were transferred to fresh media at 72 h intervals. Each treatment had 5 replications. The larvae were monitored on D, DM, FF and LPH media and rice plant at (±0.1 °C) 15, 20, 25, 30, 35, and 40 °C to verify their effects and optimum temperature for development (adult emergence) on the media. To assess food conversion rate (ratio of starved (st.) wt. and fresh (fr.) wt. % i.e. physiological development or growth index), field collected, early first instar larvae (70 for each medium) were released on rice plants and on different media containing tetracycline and maintained at ambient temperature (30±0.1 °C) and humidity (85 ± 3% RH). The insects were changed to fresh medium at 48 h intervals. Fresh weight of 10 larvae of each medium was recorded at the end of each life stage and put individually in sterile tubes without food covering the open ends with insect proof netlon. After 12 h, weight of the insects was recorded and growth index (st. wt./fr. wt.%) was calculated for each medium.

The first instar LF larvae (1d old) were collected from the field and starved overnight to reduce natural microbial load of the gut. Subsequently the larvae were reared for 48 h on D and FF diets containing 40 mg/l tetracycline to kill the gut bacteria followed by another 72 h on the same media without the antibiotic to nullify the effect of the antibiotic. By this time, the larvae attained the third instar stage. Ten third instar larvae were released on each of the D and FF media without antibiotic but containing 0–$10^5$ spore-crystal/ml of the Bt var. *kurstaki* isolated from the commercial formulations halt, dipel and biolep, and the indigenous Bt isolates var. *morrisoni, tolworthi* and *thompsoni*. Death of the larvae was recorded at 12 h intervals and median lethal dose ($LC_{50}$) was estimated for each medium (Finney, 1971). All the data were analyzed by the balanced analysis of variance (ANOVA).

## RESULTS

The first instar *C. medinalis* larvae developed up to fourth instar within 13.12–14.16 d and fifth instar to moth by 17.01–18.42 d i.e. first instar to moth in about 30–32 d on RS, LF, DM, D and FF (designated as Group 1) diets, and the developmental times of different media did not differ significantly (Table 1). The larvae survived up to fourth instar stage only on SB, LPH and H (designated as Group 2) diets and required more time (15.23–15.91 d) than the corresponding time on Group 1 media. The larvae acquired the medium colour during development. On Group 1 diets, 25–99% adults emerged at 15–40 °C but 30 °C was optimum. At optimum temperature, 95-99% moths emerged on RS, D and FF diets which did not differ significantly and were more than LF and DM media (Table 2). Neither fresh nor starved weights of the first instar larvae developed on different media were significantly different (Table 3). But those of the other stages of LF were comparable either among the Group 1 or Group 2 diets and they were significantly more for the former diets (Table 3). Growth indices (st. wt./fr. wt. %) of first (3.38–6.34), second (15.78–32.14), third (21.32-42.96), fourth (43.78–79.48), fifth (60.02–66.47) instar larvae and moth (87.73–99.85) were variable for

TABLE 1. Duration of development of *C. medinalis* on different media

| Diet | Time (d) required for development | | | Colour of larvae |
|---|---|---|---|---|
| | First–Fourth instar | Fifth instar–Moth | First instar–Moth | |
| Rice plant | 13.12 | 17.01 | 30.13 | Green |
| Leaf folder | 13.62 | 17.98 | 31.60 | Brown |
| *Drosophila melanogaster* | 13.21 | 17.09 | 30.30 | Brown |
| *Drosophila* | 14.16 | 18.42 | 32.58 | Yellow |
| Fruit fly | 13.19 | 17.16 | 30.35 | Yellow |
| Stem borer | 15.23 | Not survived | NA | Brown |
| Leaf and plant hopper | 15.91 | Not survived | NA | Brown |
| *Heliothis* | 15.29 | Not survived | NA | Brown |
| LSD ($P < 0.05$) | 1.00 | 0.66 | 0.81 | – |

Results are means of 5 replications each of 20 larvae reared at 30 ± 0.1 °C; NA = Not applicable.

TABLE 2. Effect of temperature on moth emergence of *C. medinalis* on different complete diets

| Diet | Moth emergence (%) at different temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | LSD ($P < 0.05$) |
| Rice plant | 75 | 95 | 95 | 99 | 89 | 50 | 2.16 |
| Leaf Folder | 50 | 55 | 65 | 65 | 60 | 35 | 4.79 |
| *Drosophila melanogaster* | 25 | 30 | 35 | 35 | 25 | 25 | 2.11 |
| *Drosophila* | 70 | 85 | 95 | 96 | 90 | 45 | 3.44 |
| Fruit Fly | 70 | 85 | 95 | 95 | 90 | 45 | 3.09 |
| LSD ($P < 0.05$) | 4.83 | 3.32 | 3.44 | 4.60 | 5.06 | 0.36 | – |

Results are means of 5 replications each of 20 insects. The insect did not complete life cycle on the other media.

different media (Table 3). They were more on Group 1 diets than the Group 2 diets, and RS, FF and D diets showed higher indices (Table 3). Virulence ($LC_{50}$) of the indigenous Bt isolates ($26.21–31.45 \times 10^3$ spore-crystals/ml) incorporated with D and FF diets was higher than those ($6.11–8.01 \times 10^3$ spore-crystals/ml) of the commercial Bt isolates (Table 4).

## DISCUSSION

Optimum time (30–32d) (Table 1) and temperature (30 °C) (Table 2) for development of *C. medinalis* from first instar to moth stage on RS, LF, DM, D and FF (Group 1) diets at 85% RH under controlled conditions conformed with the prevailing field

TABLE 3. Fresh and starved weight of different life stages of *C. medinalis* reared on different diets

| Life stage | Weight | Weight (mg/insect) of insects reared on different diets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Rice plant | Leaf folder diet | *Drosophila* diet | *D. melanogaster* diet | Fruit fly diet | Stem borer diet | LPH diet | *Heliothis* diet | LSD ($P < 0.05$) |
| First instar | Fresh | 0.63 | 0.59 | 0.54 | 0.50 | 0.51 | 0.59 | 0.59 | 0.54 | 0.38 |
| | Starved | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| | S/F (%)* | 6.34 | 5.08 | 5.56 | 6.00 | 5.88 | 5.08 | 3.38 | 3.70 | 0.61 |
| Second instar | Fresh | 2.24 | 2.04 | 2.01 | 1.98 | 1.79 | 1.46 | 1.33 | 1.36 | 0.35 |
| | Starved | 0.72 | 0.62 | 0.63 | 0.58 | 0.56 | 0.26 | 0.21 | 0.20 | 0.23 |
| | S/F (%)* | 32.14 | 30.39 | 31.34 | 29.29 | 31.28 | 16.44 | 15.78 | 17.64 | 0.71 |
| Third instar | Fresh | 6.47 | 6.32 | 6.18 | 6.35 | 6.12 | 4.21 | 3.94 | 3.25 | 0.92 |
| | Starved | 2.78 | 2.41 | 2.33 | 2.46 | 2.33 | 0.92 | 0.84 | 0.76 | 0.31 |
| | S/F (%)* | 42.96 | 38.13 | 37.70 | 38.74 | 38.07 | 21.85 | 21.32 | 23.38 | 0.17 |
| Fourth instar | Fresh | 16.30 | 14.11 | 13.11 | 12.09 | 12.01 | 9.16 | 8.24 | 9.16 | 1.14 |
| | Starved | 9.76 | 7.82 | 9.98 | 9.61 | 9.29 | 4.14 | 4.01 | 4.01 | 0.72 |
| | S/F (%)* | 59.87 | 55.42 | 76.13 | 79.48 | 77.35 | 45.19 | 49.26 | 43.78 | 1.61 |
| Fifth instar | Fresh | 22.28 | 21.86 | 20.01 | 21.98 | 22.02 | ND | ND | ND | 1.46 |
| | Starved | 14.52 | 13.33 | 12.01 | 14.61 | 13.98 | ND | ND | ND | 1.48 |
| | S/F (%)* | 65.17 | 60.97 | 60.02 | 66.47 | 63.49 | ND | ND | ND | 2.74 |
| Pupae[a] | Fresh | 23.57 | 21.65 | 20.66 | 22.46 | 23.01 | ND | ND | ND | 1.30 |
| Moth | Fresh | 8.85 | 7.99 | 7.01 | 8.14 | 8.04 | ND | ND | ND | 0.31 |
| | Starved | 8.52 | 7.01 | 7.00 | 8.00 | 8.01 | ND | ND | ND | 0.87 |
| | S/F (%)* | 96.27 | 87.73 | 99.85 | 99.50 | 99.63 | ND | ND | ND | 0.95 |
| LSD ($P < 0.05$) | NA | 1.73 | 1.65 | 1.48 | 1.26 | 1.36 | 0.65 | 0.92 | 0.69 | – |

Results are means of 10 larvae reared at $30 \pm 0.1°C$ and the weights were taken at the end of each stage. S = starved wt., F = fresh wt., ND = Not developed. [a] Starved weight is not applicable. NA = Not applicable. *Not subjected to statistical analysis for comparison among different life stages along the diet column.

TABLE 4. Virulence of indigenous *B. thuringiensis* (Bt) isolates incorporated in different media against third instar *C. medinalis* larvae

| Bt subspecies | $LC_{50}$ (No. of spore-crystal $\times 10^3$/ml) | | |
|---|---|---|---|
| | Incorporated in *Drosophila* diet | Incorporated in fruit fly diet | LSD ($P < 0.05$) |
| *Morrisoni* | 29.18 | 29.22 | 3.29 |
| *Tolworthi* | 31.44 | 31.45 | 4.11 |
| *Thompsoni* | 26.21 | 26.91 | 3.75 |
| *Kurstaki* of halt* | 7.33 | 7.23 | 0.18 |
| *Kurstaki* of dipel* | 6.11 | 6.98 | 0.71 |
| *Kurstaki* of biolep* | 8.33 | 8.01 | 0.02 |
| LSD ($P < 0.05$) | 4.41 | 5.45 | – |

Results are mean of 3 replications. *The bacteria isolated from the formulations were tested.

temperature (29–32 °C) and humidity of occurrence of the LF in Cuttack area (Mishra *et al.*, 1999). The observations suggested that laboratory assays could be monitored at 30 °C and 85% RH. Survival of the LF larvae only up to fourth instar stage and lower growth indices (3.38–49.26%) on SB, LPH and H (Group 2) diets (Tables 1, 2) suggested that they may have nutrition deficiency (Koyama, 1988; Siddiqui and Dey, 2001) and unsuitable for bioassay. On the other hand, complete development of *C. medinalis* on Group 1 diets (Tables 1, 2) indicated that they would be complete media (Koyama, 1988; Siddiqui and Dey, 2001). But lesser moth emergence (i.e. more mortality during development) on LF and DM diets (Table 2) suggested that certain nutrients may be limited in them (Koyama, 1988; Siddiqui and Dey, 2001), therefore, less preferred for bioassay. However, among the Group 1 diets, adult emergence (96–99%) and growth indices (96.27–99.63%) were comparable on D, FF and RS at 30 °C and 85% RH which suggested that D and FF diets would be suitable for bioassay of the pathogens in the laboratory. The D and FF diets can replace rice plants and being commercial products without host plant factor, it is advantageous to extensively use them for reliable bioassay of Bt. Lower lethal values ($6.11–9.93 \times 10^3$ spore-crystals/ml) of the commercial Bt isolates than those ($26.21–44.10 \times 10^3$ spore-crystals/ml) of the indigenous Bt (Table 4) proved that the latter pathogens are less effective than the former ones.

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# Effect of late planting of onion on the incidence of *Thrips tabaci* Lindemann in Ladakh, Kashmir

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ABSTRACT: Observations were made on the population of the thrips, *Thrips tabaci* on timely transplanted and late transplanted onion at Leh, Ladakh, located at 11300 feet amsl. Correlation of the thrips population with weather parameters was also examined. Timely transplanted onion suffered less thrips infestation and yield loss compared to late transplanted onion. Among the weather parameters, weekly maximum temperature showed the best correlation with thrips population.


## INTRODUCTION

In successful cultivation of onion in cold arid region (Ladakh) of Jammu and Kashmir State, onion thrips, *Thrips tabaci* Lindemann has proved to be a limiting factor. This pest has been found on 29 plant families, most commonly on plants from the Asteraceae family (16 species) followed by Fabaceae (10 species), Poaceae and Rosaceae (4 species). It has also been found on weeds, flowers, trees and on cultivated crops like wheat, corn (maize), sorghum, sugarbeet, alfalfa (lucerne), clover, soyabean, sunflower, onion, strawberry, tomato, carrot, pumpkin, garlic, and capsicum (Raspudic and Ivezic, 1998; Rao *et al.*, 1999). The nymphs and adults remain in the axil of leaves and lacerate the leaf surface to suck the oozing cell sap which leads to the development of white patches on leaves (Bangale and Jol, 1983). It has been estimated that each individual of *T. tabaci* is capable of destroying the cells of 4.93 mm surface area of leaf within 24 h (Shah *et al.*, 2005). Severe infestation results not only in drying up of young leaves, but also in substantial reduction of yield (Shah *et al.*, 2005).

The severity of this pest is known to be greatly influenced by abiotic factors (Dhiman and Sangeeta Singh, 2002; Lavekar *et al.*, 2004) and varietal attributes (Dhamaniya *et al.*, 2005). Temperature conditions affect the development of onion

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thrips, which may manifest in changes in the number of its generations and on the extent of damage. However, it is difficult to establish direct cause and effect relationship between any single climatic factor and pest activity because the effect of weather elements on pest is usually confounded. There is no record on population dynamics of thrips in cold arid region (Ladakh) of Jammu and Kashmir which is completely different from the rest of India in altitude, topography, climatic condition, duration of crop, cropping season and crop practices. Therefore, the present investigation was undertaken to study the population dynamics of onion thrips in relation to weather parameters.

## MATERIALS AND METHODS

An experiment was carried out during the years 2003 and 2004 at Field Research Laboratory, Leh (located at 11300 feet amsl) to study the population dynamics of onion thrips in relation to weather parameters with two transplanting dates i.e. 28th May and 10th June on 1000 $m^2$ area each. Onion transplanted plot was further divided into five sub plots of 20 m $\times$ 10 m. All the recommended cultural practices for this region were followed. There was no insecticidal spray during the crop growth stage. Observations of thrips population was started with the appearance of thrips and continued up to the harvesting of crop. For counting the thrips population, randomly 10 leaves (including upper, middle and lower) were selected from each plot for each date of observation. Thrips present on leaves were counted on white paper. The observations were recorded at weekly interval up to harvesting of crop. The meteorological data (minimum and maximum temperature, humidity and rainfall/ snowfall) were recorded daily to calculate the weekly mean maximum and minimum temperature and relative humidity. Weekly mean meteorological data and thrips population were used for correlation study to find out the impact of meteorological parameters on thrips population.

## RESULTS AND DISCUSSION

Results of the two years study revealed that in timely transplanted crop (28th May of year 2003), thrips appeared in third week of June while in late transplanted crop (10th June) it appeared in first week of July. Thrips population during the crop growth stage of year 2003 ranged from 1.62 to 39.08 in timely transplanted crop while in late transplanted crop it raged from 0.35 to 32.44 thrips per leaf (Table 1). Similarly, in year 2004, it was 1.82 to 43.52 and 1.21 to 27.08 thrips per leaf, respectively. There was significant difference in thrips population recorded in different standard week during both the years. Significantly highest peak population was detected in third week of July in timely transplanted crop while in late transplanted crop it was in second week of August during the year 2003 (Tables 1 and 2). Similar trend of thrips population was recorded in cropping season of year 2004 wherein peak period was noticed in third week of July in timely transplanted crop while in first week of August in late transplanted crop (Tables 3 and 4) which was significantly highest compared to rest of

TABLE 1. Thrips population during different standard week of timely transplanted crop in the year 2003

| Date of observation | Mean no. of thrips per leaf | Temperature (°C) Max. | Temperature (°C) Min. | Humidity (%) Max. | Humidity (%) Min. | Rainfall (mm) | Cloudiness |
|---|---|---|---|---|---|---|---|
| 15.06.03 | 1.62 | 21.95 | 9.80 | 44.00 | 22.80 | – | – |
| 22.06.03 | 3.66 | 24.47 | 11.08 | 47.42 | 23.71 | – | – |
| 29.06.03 | 12.46 | 26.11 | 13.22 | 47.14 | 21.71 | – | – |
| 06.07.03 | 20.38 | 27.55 | 13.54 | 43.85 | 20.85 | – | – |
| 13.07.03 | 34.18 | 27.28 | 13.64 | 42.57 | 21.42 | – | C |
| 20.07.03 | 39.08 | 29.14 | 13.71 | 42.75 | 20.57 | 1.5 | C |
| 27.07.03 | 34.44 | 31.60 | 16.51 | 43.85 | 19.71 | – | – |
| 03.08.03 | 25.44 | 29.57 | 15.94 | 47.82 | 20.42 | – | – |
| 10.09.03 | 16.76 | 27.21 | 13.84 | 48.57 | 20.85 | – | – |
| 17.08.03 | 9.68 | 27.61 | 12.91 | 59.28 | 18.85 | 14.8 | – |
| 24.08.03 | 2.38 | 23.98 | 10.82 | 68.85 | 27.42 | – | – |
| CD (at 5%) | 3.46 | | | | | | |

the observation dates. Present finding is in agreement with the results of Deligeorgidis *et al.* (2002) who stated that highest population density of thrips was recorded in July and August in onion crop. During study highest thrips population was recorded at 27.3 to 31.6°C temperature with 39.64 to 45.8% relative humidity. Hamdy and Salem (1994) reported that most favourable climatic conditions for the development of the pest seemed to be about 21.1–23.6°C and 52% R. H. The increase in infestation of thrips population during June and July could be due to the congenial temperature and relative humidity which was prevalent during these months. Declining trend of thrips population was recorded after third week of July and August during timely and late transplanted crop, respectively, which could be mainly due to the fall in minimum and maximum temperature.

Correlation study revealed that there was strong correlation between thrips population and meteorological data. Significantly best correlation was recorded between thrips population and weekly maximum temperature in timely transplanted crop $\{r = 0.835$ (2003), $r = 0.958$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$ thereby indicating that maximum temperature favoured multiplication of thrips population while in late transplanted crop, where fall of temperature was recorded, did not $\{r = 0.445$(2003), $r = 0.250$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$. Jimenez-Jimenez and Roscandido Alfonso (1996) reported that increase in temperature resulted in faster development and in higher number of generations of onion thrips because females at the highest temperature laid the most eggs and lived longest (Bergant *et al.*, 2003).

During the study weekly mean relative humidity was found to be more or less constant in relation to trend of thrips population build up. There was no significant correlation between thrips population and maximum relative humidity in timely $\{r = 0.559$ (2003), $r = 0.600$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$ as well as late transplanted crop $\{r = 0.062$ (2003), $r = 0.379$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$.

TABLE 2. Thrips population during different standard week of late transplanted crop in the year 2003

| Date of observation | Mean no. of thrips per leaf | Temperature (°C) Max. | Min. | Humidity (%) Max. | Min. | Rainfall (mm) | Cloudiness |
|---|---|---|---|---|---|---|---|
| 01.07.03 | 0.35 | 26.62 | 13.14 | 40.00 | 20.85 | 1.5 | – |
| 08.07.03 | 1.46 | 27.10 | 13.70 | 40.85 | 21.57 | – | – |
| 15.07.03 | 9.46 | 27.98 | 13.38 | 40.14 | 21.85 | – | – |
| 22.07.03 | 18.38 | 28.72 | 13.77 | 42.14 | 19.85 | – | – |
| 29.07.03 | 24.18 | 30.48 | 15.32 | 40.85 | 20.28 | – | – |
| 05.08.03 | 31.60 | 29.10 | 14.84 | 45.58 | 20.14 | – | – |
| 12.08.03 | 32.44 | 28.02 | 13.97 | 43.71 | 21.28 | – | C |
| 19.08.03 | 26.44 | 26.44 | 12.01 | 63.42 | 21.71 | 14.8 | C |
| 26.08.03 | 20.76 | 23.45 | 11.64 | 63.40 | 41.42 | – | – |
| 2.09.03 | 10.68 | 22.35 | 10.61 | 62.00 | 27.42 | 2.0 | – |
| 09.09.03 | 3.38 | 21.58 | 9.97 | 62.00 | 23.00 | – | – |
| CD (at 5%) | 4.23 | | | | | | |

TABLE 3. Thrips population during different standard week of timely transplanted crop in the year 2004

| Date of observation | Mean no. of thrips per leaf | Temperature (°C) Max. | Min. | Humidity (%) Max. | Min. | Rainfall (mm) | Cloudiness |
|---|---|---|---|---|---|---|---|
| 13.06.04 | 1.82 | 21.00 | 10.70 | 37.00 | 21.8 | – | – |
| 20.06.04 | 4.88 | 22.35 | 12.83 | 40.20 | 22.1 | – | – |
| 27.06.04 | 15.52 | 25.32 | 12.25 | 43.14 | 20.62 | – | – |
| 04.07.04 | 18.14 | 27.55 | 13.46 | 43.57 | 23.35 | – | C |
| 11.07.04 | 29.62 | 28.50 | 13.20 | 43.85 | 21.62 | 3.6 | C |
| 18.07.04 | 43.52 | 30.93 | 13.96 | 45.85 | 20.57 | – | C |
| 25.07.04 | 30.2 | 29.68 | 14.50 | 47.85 | 19.92 | 2.3 | C |
| 01.08.04 | 23.4 | 25.65 | 13.55 | 35.82 | 20.62 | – | – |
| 08.08.04 | 11.92 | 24.80 | 12.42 | 35.57 | 20.85 | 2.1 | C |
| 15.08.04 | 7.94 | 24.0 | 10.11 | 39.28 | 21.85 | – | – |
| 22.08.04 | 3.24 | 21.81 | 9.27 | 35.85 | 22.34 | – | – |
| CD (at 5%) | 4.87 | | | | | | |

The fluctuation of relative humidity due to rainfall in the month of July and August did not favour multiplication of thrips population. Hamdy and Salem (1994) reported that density of the thrips was significantly and positively affected by temperature but significantly and negatively affected by relative humidity. Domiciano *et al.* (1993) reported that thrips population was negatively correlated with relative humidity and positively with temperature.

Rainfall in the months of July and August did not favour multiplication of thrips population. However, there was positive correlation between rainfall and thrips

TABLE 4. Thrips population during different standard week of late transplanted crop in the year 2004

| Date of observation | Mean no. of thrips per leaf | Temperature (°C) Max. | Min. | Humidity (%) Max. | Min. | Rainfall (mm) | Cloudiness |
|---|---|---|---|---|---|---|---|
| 28.06.04 | 1.21 | 25.27 | 10.14 | 39.35 | 22.65 | – | – |
| 05.07.04 | 1.66 | 26.98 | 11.30 | 39.97 | 22.71 | – | – |
| 12.07.04 | 11.46 | 27.38 | 12.78 | 40.26 | 21.85 | 2.5 | C |
| 19.07.04 | 13.38 | 27.98 | 12.96 | 40.67 | 24.38 | – | C |
| 26.07.04 | 22.18 | 28.97 | 13.32 | 42.83 | 25.30 | 9.6 | C |
| 02.08.04 | 27.08 | 27.32 | 12.84 | 39.64 | 23.14 | 3.5 | C |
| 09.08.04 | 26.63 | 23.51 | 11.97 | 38.71 | 21.35 | – | – |
| 16.08.04 | 25.21 | 22.27 | 10.61 | 36.42 | 19.67 | – | – |
| 21.08.04 | 13.76 | 21.43 | 10.00 | 35.67 | 19.69 | – | – |
| 28.08.04 | 4.26 | 20.54 | 9.96 | 32.30 | 20.21 | – | – |
| 04.09.04 | 0.62 | 20.08 | 9.67 | 32.00 | 20.92 | – | – |
| CD (at 5%) | 4.25 | | | | | | |

population except in timely transplanted crop of year 2003 where negative correlation was found. Domiciano *et al.* (1993) also noticed that there was enhancement of thrips population with relatively higher temperatures (20–29°C) together with absence of rainfall. The density of thrips increased with increase in temperature combined with lack of rain (Lorini and Dezordi, 1990). Murai (2000) reported similar findings. According to him developmental rates increased linearly as temperature increased. However, significantly strong correlation was recorded with thrips population and cumulative effect of average weekly temperature and humidity in timely transplanted crop $\{r = 0.754$ (2003), $r = 0.894$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$ while in late transplanted crops the low positive correlation was non-significant $\{r = 0.601$ (2003), $r = 0.145$ (2004) and $t$ $(n-2)$ at $5\% = 0.602\}$.

During both the years of study, thrips population could not be traced in the last week of August and second week of September in timely and late transplanted crop, respectively. In timely transplanted crop, infestation of thrips was higher which might be due to optimum weather condition which proved to be more favourable for multiplication of thrips compared to late transplanted crop. However, timely transplanted crop reach ripening stage when the population of thrips was higher due to which the yield loss was comparatively lower than the late grown crop where the thrips population was higher at the early stage of crop in the first fortnight of August which resulted in higher yield loss.

It may be concluded that timely transplanting (till 28th May) of onion in Ladakh condition will cause less infestation of thrips and yield loss compared to late transplanting (after 10th June). Late transplanting of onion will also be influenced by adverse weather condition because reduction in temperature very common from August onward will also influence bulb setting and ripening of onion.

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# Host plant mediated variations in resin producing efficiency of Indian lac insect, *Kerria lacca* (Kerr) (Homoptera: Coccoidea: Tachardiidae)

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ABSTRACT: The two strains viz. *rangeeni* and *kusmi* of the Indian lac insect, *Kerria lacca* (Kerr) were cultured on different plant species to study their resin producing efficiency; *kusmi* strain performing much better than *rangeeni*. Resin production by individual female lac insect was the highest on *Schleichera oleosa* (22.84 mg) followed by *Acacia auriculiformis* (18.9 mg), *Flemingia macrophylla* (9.43 mg) and *Cucurbita moschata* fruits (6.11 mg) for *kusmi* and *A. auriculiformis* (9.09 mg) followed by *Butea monosperma* (8.76 mg), *F. macrophylla* (7.49 mg) and *C. moschata* fruits (6 mg) for *rangeeni* strain. A strong and positive correlation was recorded between cell size and weight of resin produced. A higher resin weight:cell size ratio of 6.452 in *S. oleosa* for *kusmi* and 2.932 in *A. auriculiformis* for *rangeeni* strain indicated suitability of the host plant for lac cultivation. 

KEYWORDS: Indian lac insect, *Kerria lacca*, resin production, host mediated variation

## INTRODUCTION

Indian lac insect, *Kerria lacca* (Kerr) is an economically important insect as it secretes resin along with lac dye and wax which find multifarious uses in industrial and household applications and are important export commodities. Although about 400 plant species have been reported to carry lac insects, only some of them can be utilized for lac cultivation. Choice of suitable lac-host plant is therefore an important consideration for profitable cultivation of lac. Besides other economic attributes, size and weight of the female lac cell are important parameters as performance of lac host varieties is evaluated in terms of thickness of the lac encrustation which ultimately determines lac crop yield. However, precise information on effect of host plants on

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the amount of the resin secreted by the lac insect is still lacking. Hence the study was initiated on this aspect of lac insect-host plant interaction.

## MATERIALS AND METHODS

Lac culture of *kusmi* strain was maintained on kusum (*Schleichera oleosa*), akashmani (*Acacia auriculiformis*), bhalia (*Flemingia macrophylla*) and pumpkin (*Cucurbita moschata*) fruits; and *rangeeni* strain on palas (*Butea monosperma*), *A. auriculiformis*, *F. macrophylla* and *C. moschata* fruits. *S. oleosa, B. monosperma* and *A. auriculiformis* are tree species identified in the field and were pruned before inoculation of lac insect as per recommended schedule of lac cultivation. *F. macrophylla,* a small bushy plant, was grown in earthen pots under semi-field condition; while ripened fruits of *C. moschata* were kept in a wooden box having glass in front and metal sieve on other sides. The inoculation of lac insect was done in June-July. The *rangeeni* crop matured in October-November and the *kusmi* in January-February.

The study was confined to female lac insects as the males are known to contribute very little towards resin production. As the lac larvae tend to settle in close proximity, lac secreted by the insects coalesces to form a continuous encrustation. Therefore, the cultures were manually thinned out and isolated individual female lac insect cells were collected at crop maturity for assessing lac production. Each cell was kept separately in five-ml glass vial for about a month till all the nymphs emerged and the lac insect inside became dead and dry. The weight of each intact cell, vertical diameter and horizontal diameter were recorded. The mean of horizontal and vertical diameters was treated as the index of cell size. The cells were broken open and the resin was separated from the insect body and weighed to determine size / body weight ratio. The significance of the variations in the data was tested by DMRT.

## RESULTS AND DISCUSSION

Average mean diameter of a cell in *kusmi* strain was 3.02, 3.16, 3.5 and 3.54 mm on *C. moschata*, *F. macrophylla, A. auriculiformis*, and *S. oleosa*, respectively (Table 1). Resin produced by individual female lac cell varied significantly. It ranged between 6.11 mg on *C. moschata* fruits to 22.84 mg on *S. oleosa.* Resin produced per unit size of the cell was the highest (6.452) on *S. oleosa* followed by *A. auriculiformis* (5.4), *F. macrophylla* (2.984) and *C. moschata* (2.023). Average resin production on different lac hosts in ascending order was *C. moschata* fruits $<$ *F. macrophylla*, $<$ *A. auriculiformis* $=$ *S. oleosa*. Very high intra-strain variations were observed in resin producing efficiency of lac insect even when cultured on the same host plant.

Average mean diameter of a cell in *rangeeni* strain was 3.1, 3.17, 3.19 and 3.22 mm respectively on *A. auriculiformis, F. macrophylla, C. moschata*, and *B. monosperma* (Table 1). Resin produced per unit size of the cell was the highest (2.932) on *A. auriculiformis*, followed by *B. monosperma* (2.72), *F. macrophylla* (2.363) and *C. moschata* (1.881). Resin produced by individual female lac cell varied significantly. It ranged between 6 mg on *C. moschata* fruits to 9.09 mg on *A. auriculiformis.* Average

TABLE 1. Size and weight of lac cell of *Kerria lacca* grown on different host-plants.

| Host | Cell diameter (mm) | | Cell weight (mg) | | Resin weight (mg) | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| *Schleichera oleosa* (kusum) | 3.54[a] | – | 25.80[a] | – | 22.84[a] | – |
| *Butea monosperma* (palas) | – | 3.22[a] | – | 10.55[a] | – | 8.76[a] |
| *Acacia auriculiformis* (akashmani) | 3.50[a] | 3.10[a] | 21.74[b] | 10.94[a] | 18.90[b] | 9.09[a] |
| *Flemingia macrophylla* (bhalia) | 3.16[b] | 3.17[a] | 10.99[c] | 8.74[b] | 9.43[c] | 7.49[b] |
| *Cucurbita moschata* (pumpkin fruits) | 3.02[b] | 3.19[a] | 8.08[d] | 8.91[b] | 6.11[d] | 6.00[c] |
| Average | 3.40 | 3.17 | 19.51 | 10.01 | 16.96 | 8.07 |

A, *kusmi*; B, *rangeeni*

* Values in each column indicated by the same letter are on par (DMRT).

resin production on different lac hosts in ascending order was *C. moschata* fruits > *F. macrophylla* > *B. monosperma* > *A. auriculiformis*.

Average resin produced by cells of *kusmi* strain (16.96 mg) is more than twice that of the *rangeeni* cells (8.07 mg). Resin produced per unit size of the cell is more in *kusmi* (4.99 mg/mm) than *rangeeni* strain (2.55 mg/mm). Horizontal diameter of the cell was more than vertical diameter confirming the globular shape of the cell. Weight of the same size cell per female on different host plants showed significant differences demonstrating the effect of host on resin productivity of the insect (Figs. 1 and 2). A strong and positive correlation was recorded between size of the cell and the resin produced on all the host plants for both the strains. Higher values of coefficient of regression in *S. oleosa* and *A. auriculiformis* for *kusmi* strain and *B. monosperma* in *rangeeni* strain corroborate the fact that a good lac host allows full manifestation of the resin producing potential of the lac insect.

Resin producing efficiency of lac insects is high on tree hosts in comparison to *F. macrophylla* (a shrub) and the pumpkin fruit. Lac insect feeds on phloem sap of the plant (Krishnaswami *et al.*, 1964). Sreenivasaya (1924) has described that sucking of phloem sap in lac insects is passive which as a function of phloem turgor has a substantial role in the supply of food to the insects. Auclair (1963) has reported that the exudation rate of phloem sap through excised stylets in aphids is about an order of magnitude lower in herbaceous plants relative to woody plants. Considering the passive feeding habit of lac insect, higher turgor pressure may lead to greater food ingestion and thus higher resin output and vice-versa. Kloft (1977) has also

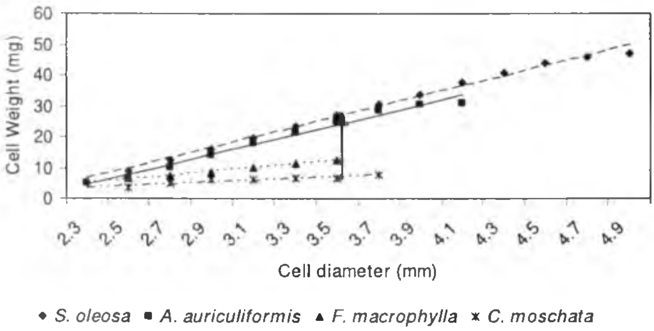


FIGURE 1. Resin productivity as affected by host-plant in *kusmi* strain *Kerria lacca* during winter season crop. Arrow indicates the difference in weight of resin secreted on different host-plants by female lac insect of the same size ($R^2$ = 0.4152 in *C. moschata* to 0.9499 in *S. oleosa*)

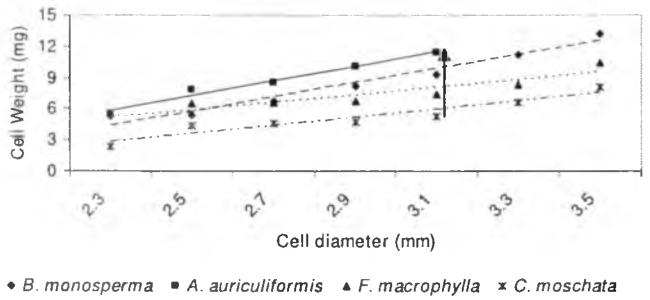


FIGURE 2. Resin productivity as affected by host-plant in *rangeeni* strain of*Kerria lacca* during rainy season crop. Arrow indicates the difference in weight of resin secreted on different host-plants by female lac insect of the same size ($R^2$ = 0.6774 in *F. macrophylla* to 0.899 in *B. monosperma*)

reported that insects feeding on non-host plants suddenly cease feeding, withdraw their stylets and leave the plant. But in case of lac insects, once they are settled at one place they do not move. Therefore, it is likely that by feeding on phloem of a less suitable host, lac insects do not escape ingesting or coming into contact with plant's defensive chemicals, and so their ability to detoxify them, or avoid including their production may result in varying yield of lac on different species of the plants and sometimes between different genotypes of the same host-plant. Edmund and Alstad (1978) while studying *Nuculaspis californica* strongly suggested that deviation in susceptibility of a host-plant species is caused by intra specific variation in the host-plant defence. Lac insects have been found to be very specific in manifestation of their biological attributes not only to the host species, specific varieties and even to individual phenotype of host-plants (Mishra *et al.*, 1999; Srinivasan, 1956) but also to locality and season of cultivation.

Quality and quantity of amino acids present in the anal fluid (honeydew) of the lac insect, *K. lacca* differs when grown on *Moghania* (= *Flemingia*) *macrophylla* and three species of *Ficus viz. F. glomerata*, *F. indica* and *F. religiosa* (Haque, 1984), which points to the difference in nutritional composition of the host plants. Therefore, it is imperative that nutrient requirement of the lac insect should be managed properly through plant-hosts for better lac yield. As the lac insects are passive feeders, manipulating turgor pressure for increased feeding in the host-plant, especially the bushy hosts may help improve lac resin yield.

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# Effect of amino acid supplementation on the activity of glutamate-oxaloacetate transaminase in the silkworm, *Bombyx mori* L.

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ABSTRACT: The activity of Glutamate-oxaloacetate transaminase (GOT) (L-Aspartate: 2-oxoglutarate transaminase, E.C. 2.6.1.1) in midgut, haemolymph and silk gland during the fifth instar larval development of Polyvoltine (PV), Bivoltine (BV) and Cross breed (CB) of *Bombyx mori*, fed with different concentrations (0.1% & 0.5%) of alanine was studied. The GOT activity in the midgut of PV and BV increased with both the concentrations of alanine, while in CB, a decrease with 0.1% alanine was observed. In the haemolymph of PV, BV and CB the GOT activity decreased with both the concentration of alanine. In silk gland of PV and CB, the GOT activity decreased with both the concentrations of alanine. In BV, the enzyme activity increased with both the concentrations of alanine. The results are discussed in relation to the accumulation, interconversion and transport of specific amino acid in the different tissues for silk protein synthesis during fifth instar development of *Bombyx mori*. 

KEYWORDS: *Bombyx mori*, transaminase, amino acid supplementation

## INTRODUCTION

In insects, proteins and amino acids play a key role in overall metabolism at different stages of development. Glutamate plays a central role in metabolism of amino acids, since it is formed by the transamination of nearly all the amino acids and is chemically related to 2-oxoglutarate ($\alpha$-ketoglutarate), a key intermediate in the Krebs cycle. The silkworm requires 18 amino acids for its nutrition, of which 10 essential amino acids and proline were demonstrated by deletion experiments (Aira and Ito, 1967). The silkworm shows a poor growth on diets containing only the 10 essential amino acids and proline but on the addition of acidic amino acids like aspartic acid or glutamic acid, it shows the normal growth (Ito and Arai, 1967; Ito, 1967; Aira and Ito, 1967). It has been shown that these two acidic amino acids act as donors of amino groups in transamination reactions (Bheemeswar and Sreenivasaya, 1952).

The activity of transaminases in various tissues of silkworm have been reported (Ravikumar and Sarangi, 2005). McAllan and Chefurka (1961) have shown that the activity of transaminase increased during larval development and pupal differentiation. The rate of transamination reaction has been shown to be correlated with the degree of production of silk proteins in the silk gland of silkworm (Klunova *et al.*, 1976). Several literature revealed that the growth and development of silkworm and the silk quality and quantity increased when mulberry leaves were fortified with essential nutrients (Mathavan *et al.*, 1984; Murthy Narasimha *et al.*, 1987; Murthy and Govindappa, 1988; Balamani *et al.*, 1995; Gouda *et al.*, 1998). However, the information on transaminase activity in silkworm with alanine supplementation during fifth instar is rather scanty. Hence an attempt has been made to study the activity of GOT in midgut, haemolymph and silk gland during last larval stage fed with different concentrations of alanine which might reflect on the interconversion of non-essential amino acid for silk protein synthesis during fifth instar larval development of *Bombyx mori*.

## MATERIALS AND METHODS

### Animal

Bivoltine (BV) ($CSR_2$), Polyvoltine (PV) (Pure Mysore) races of *B. mori* and their hybrid (CB) (PM♀ × CSR2♂) were selected for the study and reared under standard laboratory conditions according to the method Krishnaswami (1978). For the experiment, fifth instar larvae were used from first day to the spinning stage at 24 hours intervals. After fourth moult, the fifth instar larvae were segregated into three separate batches of 100 worms each. Batch-I served as the control. Batch-II and Batch-III were fed with mulberry leaves sprayed with 0.1% and 0.5% alanine, respectively to study the effect of amino acid supplementation on transaminase activity. However, the larvae were fed with normal tender leaves without amino acid supplementation immediately after resumption from the moult for one feed to activate the feeding rate of the worm. Then the worms were fed with leaves sprayed with the above concentrations *ad libitum* for four times a day. Trial experiments were conducted to fix the concentrations of alanine.

### Tissue preparation

The silkworms were pre-chilled (Boctor and Salem, 1973) and then haemolymph was collected by cutting open the caudal horn in a pre-chilled haemolymph tube containing a pinch of thiourea (Wyatt and Pan, 1978). The haemolymph was diluted with ice-cold phosphate buffer, pH 7.4, centrifuged at 3000 rpm and the supernatant was used for the enzyme assay. The midgut and silk gland were excised from the same larvae in ice-cold distilled water. A 25% (w/v) homogenate of the tissue was prepared in ice-cold phosphate buffer, pH 7.4, centrifuged at 3000 rpm and the supernatants were used as the enzyme source.

**Assay of GOT**

The activity of glutamate-oxaloacetate transminase (GOT) was assayed according to the method of Reitman and Frankel (1956) using sodium pyruvate as standard. 100 $\mu$l of enzyme was incubated with 500 $\mu$l of 0.1 M phosphate buffer, pH 7.4 containing 1 mM 2-oxoglutarate and 100 mM aspartate for 30 min at 37°C. The reaction was terminated by adding 500 $\mu$l of chromogen solution which contains 2, 4, dinitrophenyl hydrazine and 0.1N HCl. The mixture was allowed to stand for 20 min at room temperature. 5 ml of 0.4 N. NaOH was added and the absorbancy was measured after 5 min at 546 nm using Genova UV/Visible spectrophotometer. The enzyme activity was expressed as $\mu$M pyruvate formed/min/mg protein.

The enzyme specific activity of GOT is expressed as mM pyruvate formed/mg/min. The data were analyzed statistically and the mean values along with standard deviation are presented in the results.

## RESULTS

Changes in the GOT activity in midgut, haemolymph and silk gland of silkworm during fifth instar larval development are presented in the figures.

In midgut of PV, the activity of GOT showed an increase with both the concentrations of alanine from the beginning to the end of fifth instar showing a maximum level of 77.031 m mole/min/mg with 0.1% alanine (Fig. 1a) on the last day. In BV, the activity of GOT was found to increase with both the concentrations of alanine attaining the highest value of 128.669 m mole/min/mg with 0.1% alanine (Fig. 1b). In CB, the enzyme activity decreased with 0.1% alanine and showed no change with 0.5% alanine compared to control (Fig. 1c).

In haemolymph of PV, the GOT activity was higher with both the concentrations of alanine on first day (19.300 & 25.734 m mole/min/ml) compared to the control, which decreased thereafter till the end of fifth instar. In BV, the GOT activity was found to decrease significantly with both the concentrations of alanine being the lowest of 7.857 m mole/min/ml on the second day with 0.1% alanine. In CB also the enzyme activity decreased with both the concentrations of alanine compared to control being the lowest with 0.5% alanine (7.914) (Fig. 2a, b and c).

In silk gland of PV, the GOT activity was high in the control and decreased with both the concentrations of alanine showing the lowest enzyme activity of 25.563 with 0.1% alanine. In BV, both the concentrations of alanine showed an increase in enzyme activity from the beginning to the end of fifth instar attaining the highest value of 96.103 and 95.591 m mole/min/mg on the last day with 0.1% and 0.5% alanine, respectively. But in CB, both the concentrations of alanine showed a decrease in GOT activity compared to control being the lowest on the first day with 0.1% alanine (Fig. 3a, b and c).

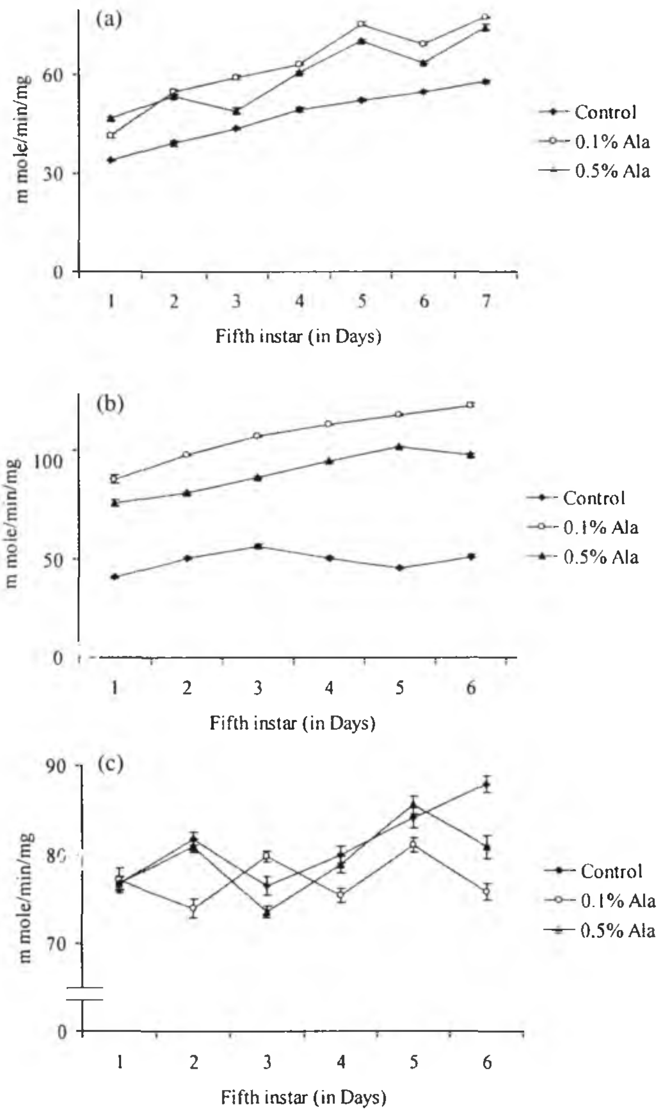


FIGURE 1. Changes in the activity of GOT in midgut of different varieties of the silkworm, *B. mori* supplemented with alanine (a) Polyvoltine, (b) Bivoltine, (c) Cross breed.

## DISCUSSION

The growth, differentiation and development in insects are closely related with the variations in the degree of protein synthesis. Transamination reactions are responsible for the synthesis of amino acids, leading from keto acids, resulting in the accumulation

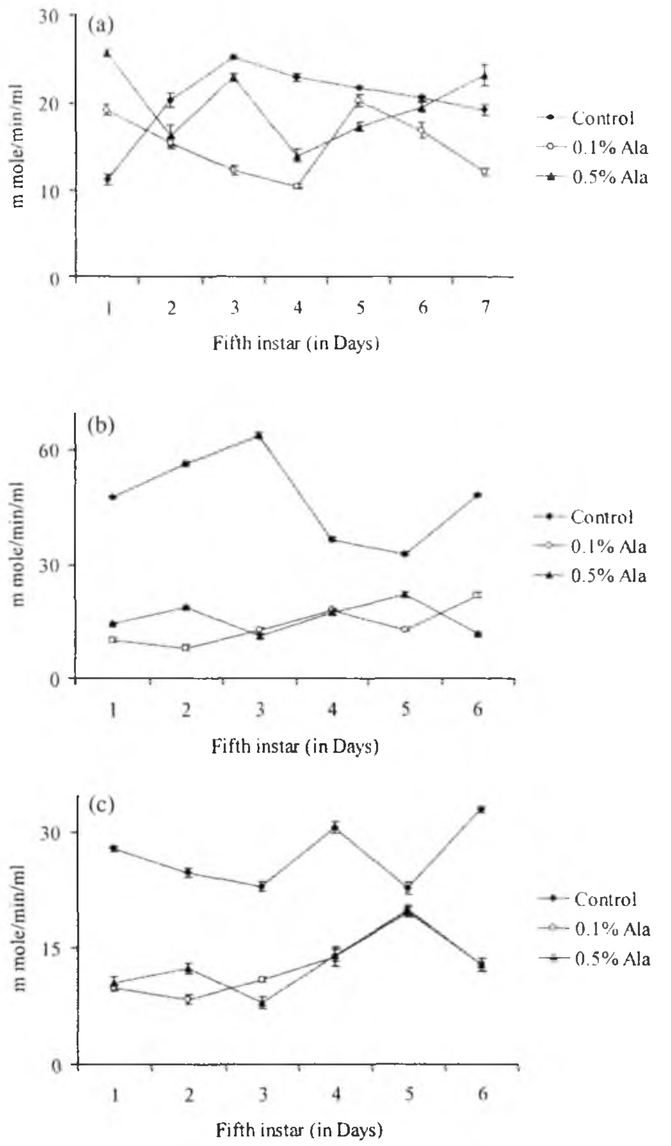


FIGURE 2. Changes in the activity of GOT in haemolymph of different varieties of the silkworm, *B. mori* supplemented with alanine (a) Polyvoltine, (b) Bivoltine, (c) Cross breed.

of specific amino acids. The most active transamination reaction involves alanine, aspartate and glutamate with corresponding keto acids (Chen and Bachmann-Diem, 1964; Chen, 1966). Thus the functions of transaminases include maintenance of amino acid pool for protein synthesis (Meister, 1965) and supply of metabolites

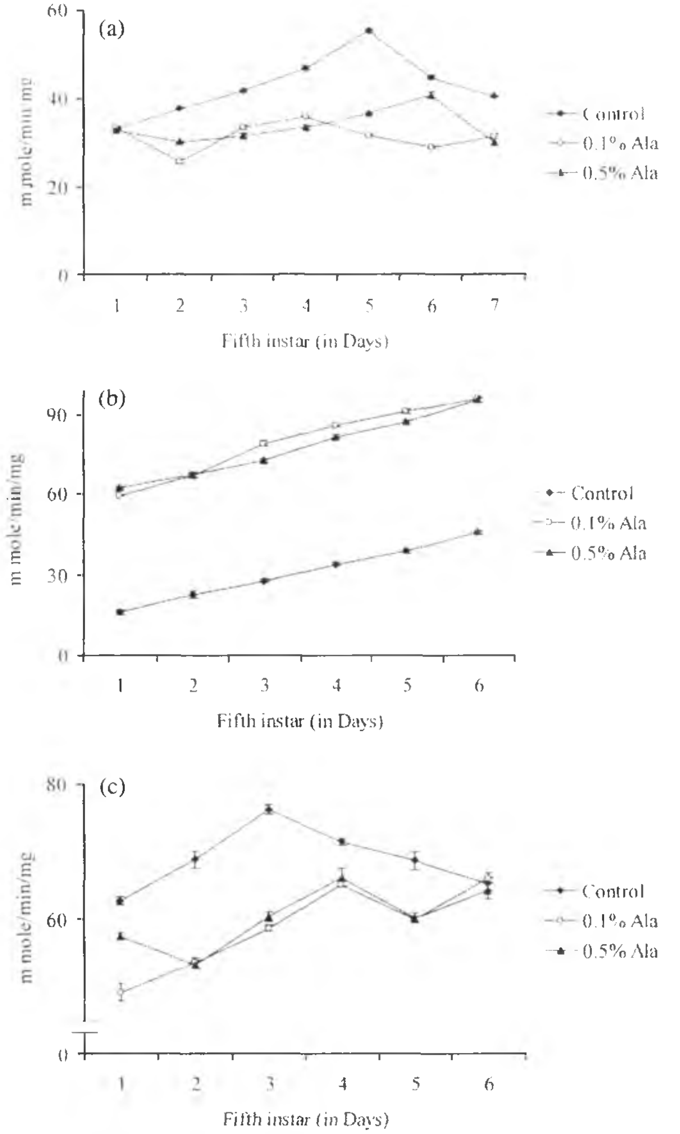


FIGURE 3. Changes in the activity of GOT in silk gland of different varieties of the silkworm, *B. mori* supplemented with alanine (a) Polyvoltine, (b) Bivoltine, (c) Cross breed.

for other metabolic functions in the body (Sacktor, 1974). In the present study the results illustrate that in the midgut, both the concentrations of alanine increased GOT activity in all the three varieties studied. This reflects that glutamate is perhaps utilized in the gut tissue for maintaining the amino acid pool in the body required for

protein synthesis in metamorphosing insect. In haemolymph, both the concentrations of alanine had no effect on GOT activity in all the three varieties studied. This shows that alanine does not interfere with GOT activity and may be utilized for other metabolic processes. Duffey (1980) has pointed out that acquiring the essential nutrients by a tissue may not be absolutely specific but depends upon the biochemical interconversion of nutrients. Hence, every physiological process seems to have specific requirements at specific concentrations beyond which the insect is incapable of utilizing. Thus the supplementation of alanine had no impact on the GOT activity in the haemolymph. In silk gland, the activity of GOT increased in BV with both the concentrations of alanine, but showed no change in PV and CB. The increase in GOT activity in BV may be due to the fact that alanine increases the concentration of glutamine, which in turn influences the enzyme activity in the body. This is in accordance with the findings of Auclair (1959) which shows that alanine and aspargine cause an increase in the level of blood glutamine and aspartic acid respectively, in German roach resulting in an increase in transaminase activity. Bheemeswar and Sreenivasaya (1952) have shown the presence of transaminase activity that catalyzes the formation of glutamate in the haemolymph, gut and silk gland of the silkworm. The present study shows that there exist a varietal difference as well as dose related difference in the response of GOT activity to alanine supplementation in silkworms. BV shows a greater response by increasing the GOT activity in the silk gland whereas both PV and CB seem to be poor in utilizing the additional amino acid to build up of the amino acid pool in the silk gland required for silk protein synthesis.

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# Effect of insecticide selection pressure on the biology of the diamond back moth *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) in Himachal Pradesh

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ABSTRACT: Effect of selection pressure of endosulfan, deltamethrin and cypermethrin on the biology of the diamondback moth *Plutella xylostella* in the mid hills of Himachal Pradesh was studied. The biology of treated insects was compared with that of a susceptible population (without selection pressure). The treated insects had shorter developmental period as compared to the control. The size of adults, males as well as females, was also affected due to the constant exposure to the insecticides.


KEYWORDS: selection pressure, endosulfan, deltamethrin, cypermethrin, *Plutella xylostella*, biology

Resistance to insecticides is the most important challenge in pest control programmes. The diamondback moth *Plutella xylostella* (L.) is a destructive pest of cabbage and cauliflower and it has already developed a manifold resistance to the chemicals which are being used against it. (Shankar *et al.*, 2005; Lal *et al.*, 2005). In view of this, the effect of continuous use of the three common insecticides in Himachal Pradesh on the biology of the diamondback moth was studied in the laboratory.

The larvae of *P. xylostella* collected from different cauliflower field in Himachal Pradesh were reared in cages in the laboratory on fresh cauliflower leaves. The adults were maintained in cages provided with 10 per cent sugar solution as food, and allowed to lay eggs. The first generation progeny thus obtained was treated as parent stock.

Three insecticides used in the experiment (Table 1) were prepared at the $LC_{50}$ level concentrations (Assessed in the laboratory through a preliminary bioassay procedure.) from the respective commercial formulations. The larvae emerging from the eggs laid by the moths of parent generations were reared in the laboratory on the leaves of cauliflower. The third instar larvae were treated with respective insecticide dilutions

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TABLE 1. Effect of rearing *Plutella xylostella* for four generations under insecticide stress on development of the insect

| Exposed to | Duration of development (days) | Adult longevity (days) | | Length (mm) | | | Breadth (mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Pupa | Male | Female | Pupa | Male | Female |
| Endosulfan | 18.60 | 7.40 | 14.00 | 6.55 | 5.82 | 6.00 | 0.66 | 11.02 | 11.83 |
| Deltamethrin | 15.30 | 7.30 | 12.40 | 6.67 | 5.74 | 6.09 | 0.57 | 10.94 | 11.76 |
| Cypermethrin | 20.00 | 8.30 | 13.80 | 6.72 | 5.71 | 6.58 | 0.58 | 10.50 | 11.64 |
| Control (water) | 23.00 | 9.20 | 15.40 | 6.10 | 6.28 | 6.93 | 0.79 | 11.97 | 13.11 |
| $CD_{P=0.05}$ | 1.64 | 0.37 | 0.42 | 0.21 | 0.24 | 0.23 | 0.02 | 0.23 | 0.22 |

and were maintained in individual rearing cages. Each treatment was replicated three times. These surviving moths were collected and used for raising four consecutive generations on cauliflower leaves.

The developmental period from egg to adult and adult longevity of males and females were studied. Also, morphometric observations were recorded on the length and breadth of eggs and larval instars of the parent as well as subsequent generations. The wing expanse of adults was measured with the help of a digital Vernier Callipers. The data were analyzed using standard statistical methods.

The developmental period and adult longevity of larvae exposed to different insecticides selection pressures was compared after four generations (Table 1).

On comparing the duration of different developmental stages of 4th generation in different selection pressures, significant difference in duration was observed. These results are in agreement with Yamada *et al.* (1993) who reported that *P. xylsotella* after 14 generations of selection with chlorofluazuron had shorter generation time and intrinsic rate of natural increase and higher reproductive rate. Lal *et al.* (2005) also reported shorter development period in resistant strains of *P. xylostella*. Verma and Ram (1973) also reported shorter larval period of malathion resistant strain of *T. castaneum*.

The total development period for the insect reared without any treatment (control) (23d) was found to be significantly higher than the duration of development for the population exposed to different insecticides. The insects exposed to deltamethrin were found to have the shortest developmental period (15.3 days) which was significantly lesser than the developmental period for the other two insecticide exposed insects.

The adult longevity was also affected by exposure to different insecticides. Males and females survived for 9.2 and 15.4 days respectively in control which was significantly higher than all the treatments. It was also lowest in the deltamethrin treated insect population.

The size of different life stages of *P. xylostella* of different strains of 4th generation was also compared (Table 1).

The pupal length was found to be significantly lesser in control (6.1 mm) as compared to all the treatments, whereas the breadth of pupa was higher in the control.

The body length of adult males of the 4th generation treated with cypermethrin (5.71mm) was significantly lesser as compared to other treatments as well as the control, whereas the body length in females was found to be lowest in the individuals reared on leaves treated with endosulfan. The body length in males as well as females in control was significantly higher than the body length in all the treatments.

The wing expanse in both males and females was significantly lesser in all treatments as compared with the control. Amongst the treatments the wing expanse in the population exposed to cypermethrin was significantly lesser than the other two treatments.

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# Biological control of *Planococcus citri* (Risso) on acid lime with *Cryptolaemus montrouzieri* Mulsant in India

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ABSTRACT: Severe incidence of the citrus mealybug *Planococcus citri* (Risso) was observed on acid lime in August 2003 in IIHR Farm in spite of regular application of conventional insecticides. The Australian ladybird beetle *Cryptolaemus montrouzieri* Mulsant when released at 2000/ac resulted in the decline of mealybug population from 126.64 to 0.4/plant during August–November 2003. A mean of 99.68% reduction in the mealybug population on acid lime was achieved by the predator within three months of its release. Weather factors did not significantly affect the mealybug population and the reduction of *P. citri* was attributed mainly to the predation by *C. montrouzieri*. 

KEYWORDS: acid lime, mealybug, *Planococcus citri*, *Cryptolaemus montrouzieri*

In recent years, mealybugs have become an increasing threat to citrus cultivation in North East Region and peninsular India. Among the mealybug species reported, *Planococcus citri* (Risso) causes widespread damage to acid lime and other citrus species grown in India (Mani, 1994; Konar, 1998; Rao *et al.*, 2001). Insecticide use is not fully effective in controlling the mealybugs, and it often causes pest outbreak in addition to residue hazards. Hence biological control is being explored as a better option for solving the mealybug problem. The efficacy of exotic parasitoid *Leptomastix dactylopii* How. in controlling *P. citri* on citrus had been evaluated in India (Krishnamoorthy and Singh, 1987). The performance of the Australian ladybird beetle *Cryptolaemus montrouzieri* Mulsant against *P. citri* has also been documented from several other countries. The present investigation was carried out to evaluate the efficacy of *C. montrouzieri* on acid lime (*Citrus aurantifolia* Swingle) at IIHR Farm, Bangalore North, India.

*Cryptolaemus montrouzieri* was multiplied on mealybug-infested pumpkin fruits (*Cucurbita moschata* Linn.) as described by Chacko *et al.* (1978). In the acid lime

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TABLE 1. Population of citrus mealybug *Planococcus citri* and the released predator, *Cryptolaemus montrouzieri* on acid lime

| Date of observation | Population /plant (4 shoots) | |
|---|---|---|
| | Mealybug | *C. montrouzieri* |
| 03-8-2003 | 126.64 ± 22.16 | 0 |
| 17-8-2003 | 110.30 ± 10.15 | 9.46 ± 3.16 |
| 05-9-2003 | 79.20 ± 7.24 | 8.50 ± 1.30 |
| 18-9-2003 | 48.60 ± 5.16 | 5.46 ± 2.14 |
| 01-10-2003 | 24.40 ± 2.30 | 3.24 ± 0.62 |
| 16-10-2003 | 2.50 ± 0.62 | 1.83 ± 1.10 |
| 02-11-2003 | 0.40 ± 0.28 | 0.82 ± 0.48 |

orchard at IIHR, severe mealybug damage was observed in August 2003. A total of 190 six year-old acid lime plants were present in this one acre orchard. Ants were controlled by applying chlorpyrifos 0.05% in the ant holes located in the orchard 15 days prior to the predator release. Application of insecticides was suspended in the acid lime orchard a fortnight before the releases of the predator and during the period of observation. A total of 2000 larvae of *C. montrouzieri* were released in the orchard in August 2003.

Prior and subsequent to the release of the predator, the population of mealybugs, *C. montrouzieri* and other natural enemies, were recorded at about 15 day intervals on 10 randomly selected infested trees. Four shoots of 30 cm length were removed from each tree and brought to the laboratory. After counting the live mealybugs and predators, the samples were kept over pumpkins in wooden cages to record the emergence of parasitoids and predators. Weather parameters were recorded during the study period to determine their influence, if any, in the suppression of *P. citri* on acid lime.

The population trend of the mealybug and the released predator are given in Table 1. A mean of 126.64 mealybugs/plant was observed on 3 August 2003. Following the release of *C. montrouzieri*, the mealybug population declined to 110.30/plant in the first fortnight and further reduced to the level of 79.20/plant in the second fortnight. *C. montrouzieri* was found feeding on the mealybugs throughout the study period. The plants were completely cleared of the mealybugs in three months time. Weather factors like temperature, humidity and rainfall did not have any significant influence on the mealybug population in the field. Hence the reduction of the citrus mealybug was attributed mainly to the predation by *C. montrouzieri*.

In general, *C. montrouzieri* takes 60 days after release to give substantial control of mealybugs on different crops. In the present investigation, more than 80.73% reduction in the mealybug population was recorded within 60 days of *Cryptolaemus* release on acid lime. The control of citrus mealybug was observed with second generation of *Cryptolaemus* grubs (Singh, 1978). Similar results in the control of mealybug *Ferrisia virgata* (Cockerell) on guava (Mani *et al.*, 1990), *Maconellicoccus hirsutus* (Green)

on acid lime (Mani and Krishnamoorthy, 1999) and *Nipaecoccus viridis* (Newstead) on acid lime (Mani and Krishnamoorthy, 2002) with *C. montrouzieri* were reported in India. *C. montrouzieri* gave partial to complete control of *P. citri* on citrus in Spain (Martinez Ferrer *et al.*, 2003), Turkey (Ozkan *et al.*, 2001), Eastern Australia (Wilson, 1960) and South Africa (Greathead, 1971).

In view of the limitations on the use of chemical control of *P. citri*, the scope of using *C. montrouzieri* which can be multiplied and supplied by commercial insectaries, has to be explored.


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# Incidence of bruchid, *Caryedon serratus* (Olivier) on groundnut in Jaipur, Rajasthan

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ABSTRACT: Groundnut stored in godowns at several places in Rajasthan was attacked by the bruchid, *Caryedon serratus*. About 17 to 47 percent of the pods were damaged.


Groundnut (*Arachis hypogaea* L.) is one of the important edible oilseed crop grown all over India. In store, pods and kernels are attacked by over 100 insect species (Redlings and Davis, 1982). Among them *Caryedon serratus* (Olivier) is the worst in stored unshelled groundnut (Mittal and Gupta, 1978; Connsay, 1983). Loss in dry weight to the extent of 20 per cent (Dick, 1987a) and 65 per cent (Kapadia, 1994) had been reported from India. Under heavy infestation the losses reached 60–70 per cent in Senegal and Zambia (Metakot, 1991) and 80–100 per cent in Congo (Nkouka, 1991). No systematic survey on the incidence of this pest in stored groundnut has been made in Rajasthan. Therefore, a survey was conducted in godowns of Jaipur district of Rajasthan.

The sites selected were Mukundpura, Partapura, Dadar, Ramola and Sudarshanpura. Five representative samples of stored groundnut were drawn from each godown following coning and quartering technique described by Dick (1987b). The samples from each location were pooled and from the lot one sample was taken following Dick's method.

The results (Table 1) showed that the infestation was quite high: the grub number/100 pods ranged from 19.33 to 33.33 and the percentage of damaged pods ranged from 17.33 to 47.33. The highest incidence was in Dadar. The incidence in Mukundpura and Ramola were on par and the least, while the incidence in Dadar and Sudarshanpura came on par and in between the above two extremes. The study highlight the need for adopting suitable management practices against the pest in Rajasthan.

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TABLE 1. Incidence of *Caryedon serratus* in stored groundnut

| Location | No. of grubs/100 pods | Percentage of pod damage |
|---|---|---|
| Mukundpura | $19.33^{a}$ | $17.33\ (24.59)^{a}$ |
| Ramola | $21.00^{a}$ | $19.33\ (26.08)^{a}$ |
| Dadar | $31.33^{b}$ | $27.00\ (31.26)^{b}$ |
| Partapura | 38.33 | 47.33 (43.47) |
| Sudershanpura | $26.33^{b}$ | $26.00\ (30.52)^{b}$ |
| S Em ± | 3.81 | 1.75 |
| CD at 5% | 8.38 | 3.85 |

*Figures in parentheses are arcsine percentage. Figures superscribed by the same letter in each column do not differ significantly.

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# Biological suppression of the aphid *Schoutedenia emblica* (Patel & Kulkarni) on gooseberry *Emblica officinalis* Gaertn

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ABSTRACT: Heavy population of the aphid *Schoutedenia emblica* (Patel & Kulkarni) was observed along with the coccinellid predator *Cheilomenes sexmaculata* (Fabricius) on gooseberry, *Emblica officinalis* Gaertn (= *Phyllanthus emblica* Linn.) in March 2005 at IIHR Farm , Bangalore. A mean number of 2705.4 aphids /shoot was recorded in the first week of March.The aphids were completely cleared within two months by *C. sexmaculata*. No other natural enemy was observed on the aphids. No significant changes in the abiotic factors were noted during the study period. Hence decline in the population of *S. emblica* was attributed to the activity of *C. sexmaculata*. 

KEYWORDS: gooseberry, *Emblica officinalis*, Schoutedenia emblica, Cheilomenes sexmaculata, predator, biological control

The amla aphid *Schoutedenia emblica* (Patel & Kulkarni) (= *Cerciaphis emblica* (Patel & Kulkarni)) has been reported as a serious pest of gooseberry in Maharashtra (Patel and Kulkarni, 1952), Andhra Pradesh (David, 1956), Tamil Nadu (George, 1927), Karnataka (Joshi, 2005) and Gujarat (Jhala *et al*., 2005). Nymphs and adults infest tender shoots and leaves and suck the sap. They excrete large quantity of honeydew resulting in the development of sooty mould on leaves and shoots. *Schoutedenia emblica* appeared in large numbers along with the coccinellid predator *Cheilomenes sexmaculata* (Fabricius) in March 2005 on amla plants in IIHR Farm. According to Muraleedharan *et al*. (1988), natural enemies alone if uninterrupted by insecticides, will check the aphid populations. The present investigation was undertaken to determine the impact of *C. sexmaculata* in the suppression of *S. emblica* in the infested orchard.

The field study was conducted on five-year old amla plants during March–May 2005. Fortnightly observations were made from March to May 2005. The population of aphids and its predator *C. sexmaculata* (both adults and grubs) were counted on 10 randomly selected aphid infested plants. In each plant, 4 shoots of 15 cm length

TABLE 1. Population of *Schoutenia emblica* and *Cheilomenes sexmaculata* on gooseberry

| Date | Mean population/shoot | |
|---|---|---|
| | S. emblica | *C. sexmaculata* |
| 04.03.2005 | 2705.40 | 2.40 |
| 18.03.2005 | 2130.60 | 9.80 |
| 03.04.2005 | 1264.50 | 18.00 |
| 17.04.2005 | 850.24 | 10.40 |
| 02.05.2005 | 70.50 | 6.00 |
| 16.05.2005 | 0 | 4.65 |

were chosen for recording the observations. In the present study, only *C. sexmaculata* was found feeding on *S. emblica*. There was a mean of 2705.4 aphids per plant on 4th March (Table 1). A mean of 2.4 to 18.0 *C. sexmaculata* was observed during the period of observation. The aphid population was completely wiped out by second week of May 2005. There was no significant influence of the weather factors on the aphid population during the period. The decline in the aphid population was attributed to the activity of *C. sexmaculata*.

The predator *C. sexmaculata* was able to clear the amla aphid population within two months of its appearance in the field. Similar suppression of *Toxoptera aurantii* (Boyer de Foncolombe) on acid lime had been reported earlier by Mani and Krishnamoorthy (2005). Coccinellid predator *C. sexmaculata* is reported to exert great influence on the population of aphids (Sudoi *et al*., 1996; Bhattacharyya and Dutta, 1998),

Mass production of *C. sexmaculata* has been standardized by Joshi *et al.* (2003). If *C. sexmaculata* does not appear in nature adequately, its release is suggested to suppress the aphid on gooseberry.

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# Occurrence of hyperparasitism on *Cotesia* sp. (Hymenoptera: Braconidae), an effective parasitoid of *Pericallia ricini* (Lepidoptera: Arctiidae)

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ABSTRACT: A field study revealed that *Pericallia ricini* (Lepidoptera: Arctiidae) was severely attacked by *Cotesia* sp. (Hymenoptera: Braconidae) infesting castor plants in multiple cropping system. A hyperparasitoid *Pediobius foveolatus* (Hymenoptera: Eulophidae) was found as a serious limiting factor in the population build up of *Cotesia* sp. Highest parasitism was recorded in Padappai (18.34%) followed by Mangadu (17.26%) and Poonamallee (12.6%). The parasitism was very low in Nungambakkam (9.65%), an urban area in Chennai. Percent hyperparasitism was significantly high in controlled condition (48.18%) and in Nungambakkam (47.47%). Percentage of parasitoid emergence was high in field conditions. Two to three *P. foveolatus* adults emerged from a single cocoon of the parasitoid.


KEYWORDS: *Cotesia* sp., hyperparasitism, parasitism, *Pediobius foveolatus*, *Pericallia ricini*

Parasitism and hyperparasitism in insects are important factors in biological control of agricultural pests. Insect parasitoids are better than predatory insects in many aspects such as host specificity, high host searching behaviour and enormous reproductive capacity (Bishopp, 1952). Mass culture and inundative release of parasitoids in the field does not always give satisfactory results due to many environmental factors (Rabb *et al.*, 1976) and biotic factor like hyperparasitism. The castor hairy caterpillar *Pericallia ricini* (Fab.), a major defoliator of castor and minor pest of pumpkin, gingelly, moringa, *Sesbania* and field bean (David and Kumarasamy, 1988), is attacked by a gregarious braconid parasitoid *Cotesia* (= *Apanteles*) sp. This braconid parasitoid was seen to be attacked by a eulophid hyperparasitoid (secondary parasitoid) *Pediobius foveolatus* (Crawford), which is known as a key parasitoid of *Epilachna* beetle, a serious pest of Solanaceous and Cucurbitaceous plants in India (Lal, 1961; Usman *et al.*, 1963).

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A study was undertaken to find out the percentage of parasitism in *P. ricini* by *Cotesia* sp. and percentage of hyperparasitism in *Cotesia* sp. by *P. foveolatus* in field conditions in and around Chennai and also in controlled condition and the results are discussed in this paper.

Third and fourth instar larvae of *P. ricini* were collected from castor plants planted as intercrop or border crop in groundnut, bhendi, brinjal, greens and raddish agroecosystems in Poonamalle, Maangadu and Padappai between August and November 2003 in three different days. In Nungambakkam, an urban area in the heart of the city, larvae were collected from castor plants in gardens. One hundred larvae each from three nearby locations (three replications) within each study area were collected and reared separately on fresh castor leaves in plastic containers (30 cm diameter, 8 cm depth) under controlled condition ($28 \pm 0.5$ °C; 65–70% R.h. and 11 h photoperiod). The larvae were observed daily for the emergence of parasitoid larvae. The infested larvae were separated and kept in separate plastic containers (100 ml). The number of parasitoid cocoons formed and number of parasitoids emerging were counted and recorded. Non-eclosed parasitoid cocoons were kept in small glass vials (10 ml) and hyperparasitoids emerging from them were counted and recorded.

In a laboratory study, 100 second instar *P. ricini* larvae were released on castor leaves inside a chamber (30 $cm^3$). Since many *Cotesia* sp. attack the early stages of the host (Anonymous, 1994; Reena and Goud, 2002), second instar *P. ricini* larvae were selected for this study. Ten mated females (one day old) of *Cotesia* sp. were released into the chamber to parasitize the *P. ricini* larvae. After 4 days, 10 gravid female *P. foveolatus* were released into the cage. Honey solution (20%) was supplied to the parasitoids and hyperparasitoids. The percent parasitism and hyperparasitism were recorded by the same method explained above. Data were analysed following the methods of Gomez and Gomez (1984).

Data presented in Table 1 reveal that in all the areas covered in this survey there were significant levels of *Cotesia* incidence on *P. ricini* under field conditions. Highest percentage of parasitism was recorded in Padappai (18.34%) followed by Maangadu (17.26%) and Poonamallee (12.60%). Percentage of parasitoid emergence was also significantly high in field conditions and it was recorded as 63.37, 58.32 and 57.78 percent in Mangadu, Padappai and Poonamallee respectively. In Nungambakkam, 9.65 percent larvae of *P. ricini* were seen to be parasitised by *Cotesia* sp. Under controlled conditions, the percent parasitism was recorded as 8.75 percent. Number of parasitoid cocoons per host larvae was more in Nungambakkam followed by Poonamallee, Mangadu and Padappai. In field conditions, the multiplication and population build up of the parasitoid was found high. But the parasitoid population was severely affected by the hyperparasitoid *P. foveolatus*. Percentage of parasitoid cocoons infected by the hyperparasitoid was very high and its development and emergence were also high in field conditions and hence it is likely to be a serious limiting factor in the biological control of the pest. The highest level of hyperparasitism was recorded in Nungambakkam (47.47%) followed by Poonamallee (42.21%), Padappai (41.68%) and Mangadu (36.37%). Laboratory studies also clearly showed that the

TABLE 1. Parasitism and hyperparasitism in *Pericallia ricini* in different localities of Chennai and under laboratory condition

| Locality | Percent Parasitism | Number of parasitoid cocoons per host | Percent parasitoid emergence | Percent hyper-parasitism | Number of hyper-parasitoids per *P. ricini* |
|---|---|---|---|---|---|
| Maangadu | $17.26^{a}$ | $40.37^{bc}$ | $63.37^{a}$ | $36.37^{c}$ | $30.18^{a}$ |
| Nungambakkam | $9.65^{c}$ | $43.92^{a}$ | $52.53^{c}$ | $47.47^{a}$ | $47.00^{a}$ |
| Padappai | $18.34^{a}$ | $38.61^{c}$ | $58.32^{b}$ | $41.68^{b}$ | $40.87^{a}$ |
| Poonamallee | $12.60^{b}$ | $42.51^{ab}$ | $57.78^{b}$ | $42.21^{b}$ | $46.37^{b}$ |
| Laboratory | $8.75^{c}$ | $35.71^{d}$ | $51.82^{c}$ | $48.18^{a}$ | $48.54^{c}$ |

Results are expressed as Mean ± S.E. ($n = 300$). Values carrying same alphabets in each column are not significantly different at 5% level.

build up of the parasitoid was seriously affected by hyperparasitoids (48.18%). Number of hyperparasitoids formed in a single *P. ricini* larva through *Cotesia* sp. was significantly high (48.54) in controlled conditions followed by Nungambakkam (47.00), Poonamallee (46.37), Padappai (40.87) and Mangadu (30.18).

The continued abundance of the primary parasitoids in the locality, the non-availability of the preferred host species and subsequent adaptability to the host available in plenty will lead to some parasitoids becoming a hyperparasitoid. Lal (1961) and Usman *et al.* (1963) reported that *P. foveolatus* is a natural enemy of *Epilachna* beetle, a serious pest of solanaceous and cucurbitaceous plants in India. Bhatkar and Subba Rao (1976) reported that *P. foveolatus* is a parasite of predatory ladybird beetles in India. So it is clear that *P. foveolatus* acts as a primary parasitoid or a natural enemy and also as a hyperparasitoid or a pest of natural enemies such as braconid parasitoids and ladybird beetles.

Further studies are necessary to find out the causes for hyperparasitism in *Cotesia* sp. by *P. foveolatus* and the influence of polyculture agroecosystems on parasitoids and hyperparasitoids should also be studied in detail for getting success in biological control.

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# Citrus mealybug *Planococcus citri* (Risso) (Homoptera: Pseudococcidae) – a major pest of grapes in India

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ABSTRACT: Field visits carried out in Karnataka and Maharashtra during 2005–07 revealed the presence of citrus mealybug *Planococcus citri* (Risso) causing severe damage in some of the vineyards causing 30.7 to 60.4% loss of the fruit bunches. This is the first report of *P. citri* as a major pest of grapes in India.


KEYWORDS: grapes, mealybug, *Planococcus citri*

About 90 species of insects and mites have been reported on grapevine *Vitis vinifera* L. from different grape growing areas of India (Tandon and Verghese, 1994). In recent years, mealybugs have become an increasing threat to the cultivation of grapevine causing serious losses in peninsular India. They are found on shoot, leaf, bark, stem, inflorescence and fruit bunch. Grape production is often adversely affected due to the mealybugs, the extent of damage being as much as 90% in extreme cases (Babu, 1986). Eight mealybug species have been reported on grapevine in India. Among them, the pink hibiscus mealybug *Maconellicoccus hirsutus* (Green) was reported causing wide spread damage to many grape growing areas (Mani and Thontadarya, 1987).

Fields visits were made in the grape gardens of Karnataka and Maharashtra during 2005–07 to examine fruit damage. The number of infested and clean bunches on 20 randomly selected plants were counted to determine per cent mealybug infested bunches. The investigation revealed the presence of citrus mealybug *Planococcus citri* (Risso) causing severe damage in some of the vineyards. During March 2005, 30.7% of the bunches were found completely covered by the citrus mealybug at Harohalli village in Bangalore North on Sharad Seedless in spite of taking control measures with conventional insecticides. During September 2006, *P. citri* was observed in severe form mostly confined to the shoots of all the plants of Thompson Seedless in the vineyard at Khillari village in Lathur district of Maharashtra. Severe outbreak of *P. citri* was also observed in December 2006 at Pandarpur, Solapur district of Maharashtra on Thompson Seedless on the bunches in spite of application of

conventional insecticides. A mean of 60.4% bunch infestation was observed during that time. In February 2007, a heavy incidence of *P. citri* causing up to 70% bunch damage in addition to leaf and shoot infestation was observed in vineyard located at Rahuri in Ahmednagar district of Maharashtra. In February–March 2007 the presence of *P. citri* on grapes was also noted again in many other grape growing areas of Maharashtra. It is likely to become a major pest of grapevine in the years to come in peninsular India. *P. citri* is basically a pest of citrus but also noticed frequently on other host plants including grapevine (Compere, 1939). It has been reported a severe pest of grapes in Spain (Cabaleiro and Segura, 1997), Italy (Guario and Laccone, 1996), Tunisia (Agran *et al.*, 1990), Chile (Gonzalez, 2003), Turkey (Aykac and Erguder, 1972) and many regions of erstwhile USSR (Niyazov, 1969). The present study revealed that *P. citri* is as important as *M. hirsutus* in causing losses to grape industry.

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# A new species of *Tegonotus* Nalepa (Acari: Eriophyoidea) from Bhutan

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ABSTRACT: *Tegonotus bhutanensis* n. sp., a leaf vagrant eriophyid mite infesting *Lionia ovalifolia* is described and illustrated from Bhutan. Its distinction from the related taxa and host-mite relationship are also discussed.


KEYWORDS: *Tegonotus bhutanensis* n. sp., Eriophyid mite, *Lionia ovalifolia*, Bhutan

A recent survey in different localities in the Royal Kingdom of Bhutan yielded some eriophyid specimens including a new species of *Tegonotus* Nalepa (1890), which is described and discussed in this paper. This is the first description of an eriophyid specimen from the Royal Kingdom of Bhutan. The measurements in $\mu$m of the holotype followed by the measurements of the paratypes in parenthesis are given in text.

### *Tegonotus bhutanensis* n. sp. (Figs. 1–7)

Female: Body 145(145–165) long, 57(57–65) wide, fusiform, robust, pinkish white in colour. Gnathosoma 19(18–23) long, moderately arched down; dorsal pedipalp genual seta 5(5–6) long; prodorsal shield 40(40–47) long, 57(57–67) wide, smooth, subtriangular with distinctly defined thick anterior cephalic lobe over gnathosoma base; median line present on 0.3 part from the posterior shield margin, admedian lines two in number, run posteriorly and divergent up to 0.7 part then converge to meet at the centre from where the median line starts to meet the rear shield margin, submedian lines two in number, arise slightly below the anterior shield margin, diverge up to 0.4 part and then converge to meet the dorsal tubercle; a cross like groove present on anterior shield; a few larger granules present on lateral sides of the shield; a diagonal submedian line present on postero-lateral side connecting the posterior shield margin; dorsal tubercles medium sized, centrally directed, 16 apart, situated much above the rear shield margin, prodorsal scapular seta 4(3–4) long centrally and upwardly directed. Leg I 18(18–23) long from trochanter base, femur 5(5–6) long

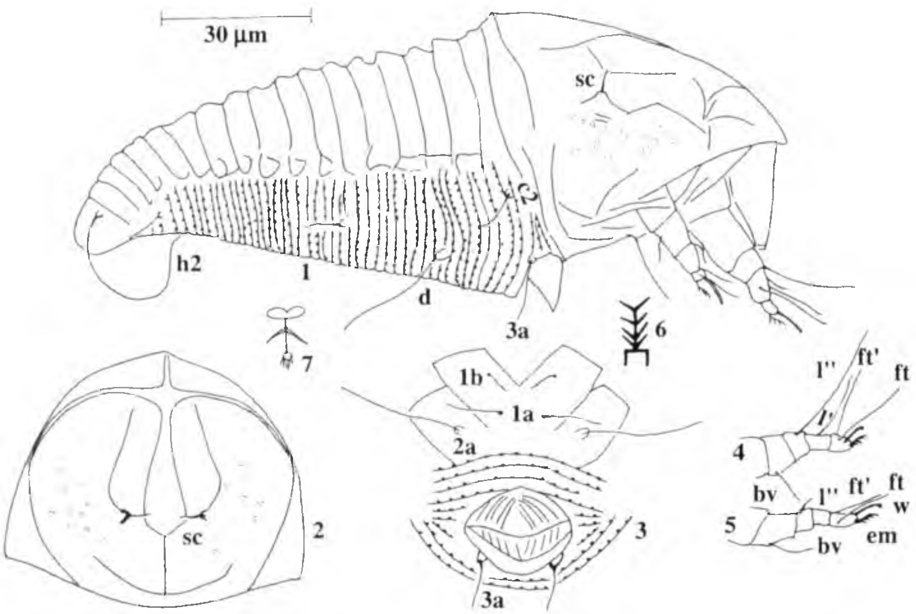


FIGURE 1. *Tegonotus bhutanensis* n. sp.; 1. Lateral view of the body; 2. Dorsal view of prodorsal shield; 3. ventral view of Coxigenital region; 4. Leg I; 5. Leg II; 6. Tarsal empodium; 7. Apodeme.

**Abbreviations**: sc = scapular seta; c2 = seta; d = seta d; e = seta e; f = seta f; h2 = seta h2; 1a= proximal seta on coxisternum I; 1b = anterolateral seta on coxisternum I; 2a = proximal seta on coxisternum II; 3a = proximal seta on coxisternum III; bv = basiventral femoral seta; $l'$ = paraxial tibial seta; $l''$ = antaxial geneal seta; **ft'** = paraxial fastigial tarsal seta; ft'' = antaxial fastigial tarsal seta; em = tarsal empodium; $\omega$ = tarsal solenidion.

with a small basiventral femoral seta 7(7–9) long; genu 3(3–4) long with antaxial genual seta 40(38–41); tibia 3(3–5) long, antaxial tibial seta 20(20–21) long; tarsus 3(3–5) long with one antaxial fastigial tarsal seta 8(8–11) long; tarsal solenidion 4(4–5) long, knobbed; empodium simple, 4-rayed; Leg II 17(17–21) long from trochanter base; femur 5(5–6) long with a small basiventral femoral seta 7(7–14) long; genu 2(2–4) long with a small antaxial genual seta 1.4 long; tibia 3(3–5) long, antaxial tibial seta 19(19–22) long; tarsus 4(4–5) long with antaxial and paraxial fastigial tarsal seta, each 9(8–10) long; tarsal solenidion 5(5–7) long, knobbed, empodium simple, 4-rayed. Coxal plates fused without distinct prosternal apodeme line, coxal surface smooth; anterolateral seta on coxisternum I (1b) slightly above the level of coxae I approximation, 1a tubercles set ahead of the line between the 2a tubercles.

Opisthosoma with 20(20–22) dorsal and 58(58–60) ventral annuli; dorsal annuli not microtuberculate, first two dorsal annuli fused to form a band-like structure just below the shield margin; ventral annuli uniformly microtuberculate, microtubercles round, bead-like, present on the posterior annular margin; presence of median and two lateral

ridges on the opisthosoma; seta c2 14(13.5–15) long on about ventral annulus 3; seta d 42(42–48) long on about ventral annulus 8(8–9); seta e 5(5.0–6.5) long on about ventral annulus 27(27–28); seta f 12(12–15) long on about ventral annulus 3 from the caudal lobe; seta h1 absent; seta h2 52(52–53) long. Epigynium 20(19–20) wide and 17(17–22) long, coverflap with longitudinal scorings in two tiers, upper tier with 10 and lower tier with 10 longitudinal scorings; proximal seta 3a 6(6–7) long.

Male: Not found

*Holotype*: Female (marked) on slide (no.1259/4/2003) Bhutan; Paro Chelella, 4.vi.2003 from *Lionia ovalefolia*, Coll. Saswati Chakrabarti. Paratypes: 5 females on the slide bearing the holotype and other three slides (nos. 1260–1262/4/2003), collection data as in holotype. These specimens are presently deposited in the collections of the Biosystematics Research Unit, Department of Zoology, University of Kalyani.

*Relation to host:* This mite is found to inhabit within ventral leaf hairs without showing any damage symptom.

## Remarks

Genus *Tegonotus* Nalepa (1890) contains 45 species (Amrine and Stasny, 1994) including 9 from India. Ghosh and Chakrabarti (1985) while describing two new species from West Bengal, India provided a key to the 12 species of *Tegonotus* known from India at that time. Amrine and Stasny (1994) have considered the following 3 species of *Tegonotus* viz., *T. birbhumenis* Das and Chakrabarti (1985), *T. cardiavagrans* Mohanasundaram (1982) and *T. coimbatorensis* Mohanasundaram (1983) under the genus *Shevtchenkella* Bagdasarian (1978). *Tegonotus bhutanensis* n. sp. in having 4-rayed empodial featherclaw, genital coverflap with longitudinal scorings in two tiers and prodorsal tubercles much above the shield margin, comes close to *T. tricarinatus* Fletchmann (1996) and *T. convolvuli* Channabasavanna (1966). The new species is also close to *T. tricarinatus* Fletchmann (1996) in having fused tergites forming a band below the shield margin. However, the present new species differs from the above two species in overall prodorsal shield structure, shorter genital setae and having smooth coxae.

*Etymology:* The specific designation *bhutanensis* is derived from Bhutan, the country from where the species was collected.

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# On a new species of *Entedonastichus* Girault (Hymenoptera: Eulophidae) from Borneo

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ABSTRACT: A new species *borneonicus* under genus *Entedonastichus* is described and illustrated. The species is closely allied to *Entedonastichus mirus* Girault in general appearance but can be easily distinguished on the basis of different proportions of antennal segments, lengths of forewing veins and general colouration.


KEYWORDS: Chalcidoidea, Eulophidae, *Entedonasticus*, new species

## INTRODUCTION

The genus *Entedonastichus* was raised by Girault (1920) based on the type species *Entedonastichus mirus*. Since then seven species are known from the world (Europe 2 spp., North America 1 sp., Australia 3 spp. and New Zealand 1 sp.) (Boucek 1988). Here a new species from Borneo collected by Dr. Steven L. Hedon is described and a key to separate it from related species is provided. This is the first record of the genus from the Oriental Region. The only host record available is that of *Entedonastichus gaussi* (Ferriere) from larvae of *Liothrips setinoids* Reufer (Thysanoptera) from Europe (Boucek 1988).

### *Entedonastichus borneonicus* sp. nov. (Figs. 1–3)

*Female*

Length 1.26 mm. Head black with brownish tinge; antenna brown; eye greyish yellow with reflecting facets; ocelli pale reflecting yellow. Mesosoma black on dorsum, dark brown at sides; legs dark brown with hind coxa darker, and apical part of fore and hind tibiae slightly paler, metatarsi of fore and hind legs paler, metatarsus of mid leg pale white. Wings hyaline with brown patch as in Fig. 1, veins brown; setae on head and mesosoma brownish black.

*Head:* Width in anterior view 1.25x as broad as long, frontal grooves meeting eyes (Fig. 2) but not reaching above median ocellus; antenna inserted below lower ocular line; eye bare in side view, 1.44x as long as broad; malar sulcus indistinct; POL 11x OOL; OOL 0.5x OD; vertex with a relatively long pair of setae, each seta 0.88x as long as eye.

*Mesosoma:* Smooth and shiny; mesoscutum with 2 relatively long setae; each seta 0.83x as long as eye; scapula with a similar long seta near tegula on either side; scutellum with a pair of long setae, each seta a little shorter than mesoscutal pair (18: 23); notauli hardly distinct; dorsellum about half as long as median length of propodeum, gently declining posteriorly (not vertical), surface smooth and shiny, median carina absent, a week line on either side (outside spiracle) present; propodeal spiracle rim fully exposed, separated from metanotum by its own diameter, callus with two relatively short setae, hardly visible. Forewing 2.1x as long as wide; SMV shorter than MV, with 3 long dorsal setae; MV 9.2x as long as STV; PMV 0.6x STV (3:5); marginal fringe 3.2x as long as STV. Mid tibial spur shorter than half width of metatarsus; hind metatarsus shorter than following segment; hind femur 4.9x as long as broad.

*Metasoma:* 1.8x as long as mesosoma; 1.36x as long as combined length of head + mesosoma; petiole and gaster smooth; ovipositor vertical.

*Male*

Unknown.

*Host*

Unknown.

*Material examined*

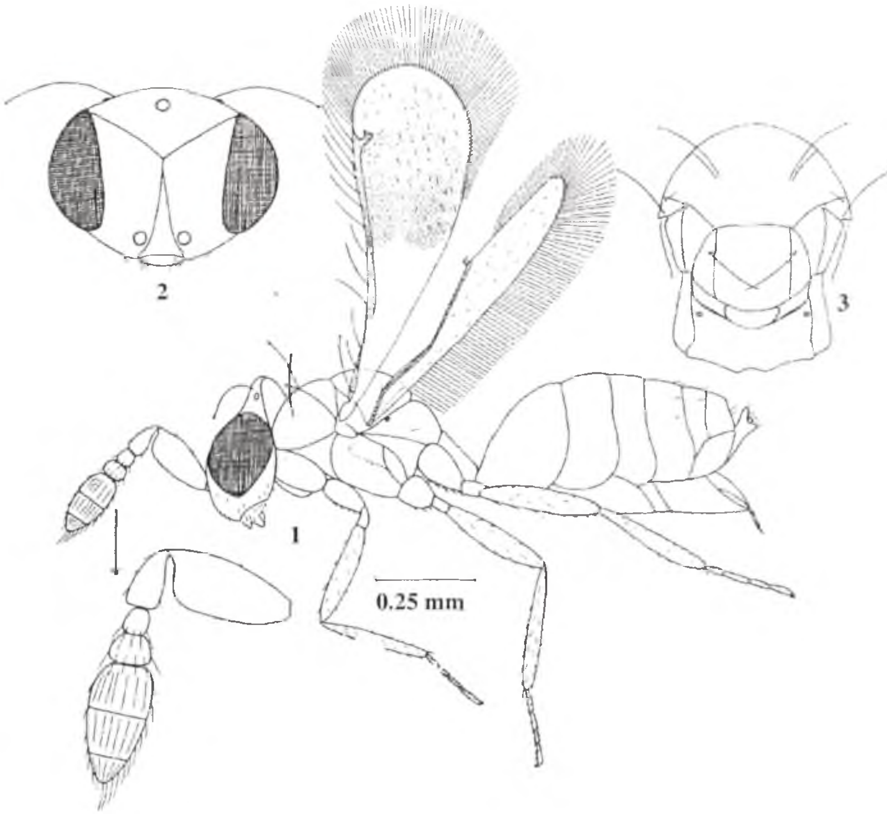
Holotype: Female: Borneo, Sarawak, SW Gunung Buda, 64 Km, S. Limbang 4° 13′ N 114°56′ E, 8-15. xi. 1996, MT. S.L. Hedeon & S. Fung (Bohart Museum, USA).

## Remarks

This new species can be separated from the allied Australian species described by Girault (1920, 1922), Erdos (1951) and Ferriere (1958) by the key given below.

### KEY TO BORNEO-AUSTRALIAN SPECIES OF *ENTEDONASTICHUS* GIRAULT

1. PMV as long as STV; marginal fringe about 3x as long as STV; forewing 3.9x as long as broad; gaster 1.25x as long as mesosoma; ocelli castaneous, scape pale, body generally black. Europe, Australia . . . . . . . . . . . . . . . *E. carbonarius* (Erdos).
- Characters not in above combination, partly or completely different . . . . . . . . . . 2




FIGURES 1–3. 1. *Entedonastichus borneonicus* sp. nov. Female. 1. Body profile; 2. Head front view; 3. Mesosoma dorsal view.

2. PMV absent; scape as long as flagellum; all tarsi and fore tibia more or less pale; general body colour black .................................. *E. dei* (Girault).
- PMV present; other characters partly or completely the same ................ 3
3. PMV a little longer than STV; forewing fringes one-fourth of wing width; scape 3.2x as long as broad; clava 1.1x as long as wide, general colour purple; fore tibia mostly, tip of middle tibia widely and tarsi pale; head and mesosoma with relatively shorter setae. Australia .......................... *E. mirus* (Girault).
- PMV 0.6x STV; forewing fringes distinctly longer than one-fourth of wing width (16:55); scape 2.44x as long as broad; clava 1.31x as long as broad; general colour partly black and partly brown; fore and midtibiae mostly brown, tarsi not quite as above; head and mesosoma with characteristic long setae (Figs. 1–3). Borneo .. ........................................... *E. borneonicus* sp. nov.

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# Bioefficacy of *Artemisia nilagirica* (Clarke) Pamp. against armyworm, *Spodoptera litura* Fab. (Lepidoptera: Noctuidae)

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ABSTRACT: Hexane, diethyl ether, dichloromethane, ethyl acetate, methanol and aqueous extracts of *Artemisia nilagirica* plant leaves were tested for their antifeedant, ovicidal, oviposition deterrent and insecticidal activities against *Spodoptera litura*. Significantly higher antifeedant and insecticidal activities were recorded in ethyl acetate extract *of A. nilagirica*; hexane extract showed statistically significant ovicidal and oviposition deterrent activity against *S. litura*.


KEYWORDS: *Spodoptera litura*, *Artemisia nilagirica*, biological activity of leaf extract

In view of the importance given to plant products in insect control strategy in recent time *Artemisia nilagirica* collected from Kodaikanal in Palani hills of Tamilnadu was assessed for its efficacy against *Spodoptera litura*. The leaves of the plant were shade dried under room temperature, powdered and extracted with hexane, diethyl ether, dichloromethane, ethyl acetate, methanol and water. Extracts were evaporated and residues were used for bioassays on fourth instar larvae of *S. litura*. The residue was dissolved in DMSO for preparing the varying concentration of the same. *S. litura* culture was established from the egg masses collected from vegetable fields (Singh, 1985).

The antifeedant activity was assessed following leaf disc bioassay method using castor leaf and antifeedant index was calculated following the formula of Jannet *et al.* (2000). Oviposition deterrent activity was studied at 5% concentration of plant extracts. The plant extract was sprayed on fresh castor leaves along with selected controls as mentioned above and placed inside cages (60 × 45 × 45 cm) and covered with mosquito net. Ten pairs of S. *litura* moths were introduced in a cage and 10% (w/v) sucrose solution with multivitamin drops was provided for adult feeding. Five replicates were maintained for control and treatments. After 48 h the number of eggs laid on treated and control leaves were recorded and the percentage of oviposition

*Corresponding author

TABLE 1. Biological activities of different solvent extracts of *Artemisia nilagirica* against fourth instar larvae of *Spodoptera litura* at 5% concentration

| Solvent | Biological activities | | | |
|---|---|---|---|---|
| | Antifeedant index | Oviposition deterrence (%) | Ovicidal activity | Insecticidal activity |
| Hexane | 46.14 | 41.17 | 51.41 | 20.12 |
| Diethyl ether | 50.06 | 34.98 | 32.11 | 28.50 |
| Dichloromethane | 42.60 | 37.20 | 37.15 | 35.21 |
| Ethyl acetate | 75.68 | 38.76 | 47.11 | 40.24 |
| Methanol | 54.72 | 34.40 | 45.68 | 31.91 |
| Water | 44.22 | 37.17 | 35.41 | 18.44 |
| Solvent control | 1.25 | 0.40 | 1.52 | 0 |
| NSKE (aqueous) | 86.30 | 51.58 | 59.12 | 48.44 |
| CD at 5% level | 1.64 | 1.44 | 1.44 | 2.86 |

deterrence was calculated by the method of Williams *et al.* (1986). For assessing ovicidal activity, scales from the egg masses of *S. litura* were carefully removed and the eggs were separated. For each replication 500 eggs were dipped in selected concentration and the percentage of ovicidal activity was calculated using Abbott's formula (Abbott, 1925). For assessing insecticidal activity, fresh castor leaves treated with 5% concentration of plant extracts were placed in round plastic trough. In each replication pre-starved (2 h) IV instar larvae of *S. litura* were introduced individually in trough and covered with muslin cloth. Five replicates were maintained and the number of dead larvae was recorded after 48 h. Percentage of larval mortality was calculated.

Data are presented in Table 1. Results revealed that the ethyl acetate extract of *A. nilagirica* at 5% concentration showed statistically significant antifeedant activity (75.68%) followed by methanol extract (54.72%). Most of the highly polar compounds present in the plant might have dissolved in the solvent applied to the foliar surface of the leaf discs suggesting a defensive role against the phytophagous insects. Oviposition deterrent activity was varied depending on the solvents used and the concentrations tested. Only hexane extract at 5% concentration showed significant oviposition deterrent activity (41.17%) when compared with NSKE aqueous extract. The remaining solvent extracts did not show any significant results (Table 1). Oviposition deterrence may be due to the presence of deterrent compounds in the plants dissolved in various solvent extracts. Srinivasan and Sundrababu (1999) reported that neem oil deterred the egg laying of *Lucinodes orbonalis*. Statistically significant ovicidal activity was recorded in the hexane extract (51.41%) of *A. nilagirica* at 5% concentration followed by ethyl acetate extract (47.11%). Significant ovicidal activity (47.01) was also recorded in the hexane extract of *A. nilagirica* at 2.5% concentration (Table 1). Diethyl ether and dichloromethane extracts did not show any promising results. The plant extracts may have one or more chemical

substances, which may block the micropyle region of the egg thereby, preventing the gaseous exchange that will ultimately kill the embryo in the egg itself. Slama (1974) reported that the incomplete blastokinesis and abnormal breakage of extra embryonic membranes in the embryo or unequal penetration of extracts through the egg chorion to different parts of egg at different times of the sensitive period could also be associated with the observations on variability of morphological effects. These findings also corroborate with present work on ovicidal activity of the plant extracts against *S. litura*. The insecticidal activity of the plant extracts may be due to the presence of insecticidal compounds in the plants. In the present study ethyl acetate extract of *A. nilagirica* at 5% concentration showed significant insecticidal activity (40.24%) when compared with all other solvent extracts of *A. nilagirica* (Table 1). NSKE showed higher biological activities when compared to all other treatments. After feeding of the larvae on treated leaves, the larvae died probably due to the arrest of various metabolic activities. In addition feeding rate of the larvae decreased; the larval development was also arrested in various instar stages. Some of the larvae died at larval pupal intermediate stage and if the larvae continued to pupal stage the newly emerged adult from the pupa showed various malformations. Our results clearly indicate that the plant posseses many useful properties to control insect pests.

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# Effect of varying levels of food supply on different life stages of ladybird predator *Coccinella transversalis* (Fabricius) (Coleoptera: Coccinellidae)

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ABSTRACT: Effect of variation in food supply on growth and food searching ability of larvae and their mortality during development were evaluated in the aphidophagous ladybird beetle *Coccinella transversalis* (F.). Adult females of this species were evaluated for ovary maturation time, reproductive period and longevity also at two food levels. At limited food supply (5 aphids per day per larva compared to a high level of 35 aphids/day/larva), larval growth and searching rate were significantly lower and developing larvae suffered higher mortality. Adult females took longer to develop ovarioles and had shorter reproductive period. Though inadequate food supply significantly affected the larvae and adult females a strong tendency to survive under food stress was evident. Results suggested that coccinellid predators will be effective biocontrol agents of pests even in heterogeneous environment.


KEYWORDS: ladybird predator, *Coccinella transversalis*, food stress, life history performance, aphid prey

Predatory ladybird beetles that forage in heterogeneous food patches are exposed to risk of uncertain availability of food. In case of larvae, somatic growth and speed of searching are crucial to their successful development in to adults (Agarwala and Yasuda, 2001). In case of adults, maturation time of ovarioles and duration of reproductive period determine the fitness of females (Dixon, 2000). Studies have shown that larvae of ladybird beetles kept on limited food supply developed in to smaller adults (Kawauchi, 1979; Agarwala *et al.*, 2001) and such females lay fewer eggs (Obrycki *et al.*, 1998). However, there is no study to show the effect of food stress on somatic growth and searching speed of larvae, and on ovariole maturation time and reproductive period of females of coccinellid predators of aphids (Hodek and Honek, 1996; Evans, 2000; Omkar and James, 2004). These aspects relating to a widely distributed aphidophagous predator, *Coccinella transversalis* (Fabricius) were studied.

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Males and ovipositing females of *C. transversalis* were collected from bean plants, *Vigna catjang*, in fields at Imphal, Manipur, north-east India. These beetles were provided with live cowpea aphids (*Aphis craccivora* Koch) until females oviposited. Eggs from these females were kept in 9 cm diameter paired Petri dishes lined at the bottom with filter paper that was dampened periodically. Ten larvae were provided each with an abundant food supply consisting of 35 aphids per day and another 10 larvae were provided each with a limited food supply consisting of 5 aphids until time to eclosion as adults. Aphids provided for first, second, and third and fourth instars grubs were second, third and adult stages, respectively. By practice, it was possible to distinguish different instars and adults of aphids by their size and external morphology.

Individual larvae were weighed in a Mettler microbalance (sensitive to 0.2 $\mu$g) at birth ($Lw_1$, < 8 hour old), and at the pre-pupa stage ($Lw_4$) by confining them individually in pre-weighed 3 cm Petri dishes. Weight gained in development ($Lw_4$–$Lw_1$) and development time (DT) of individual larvae in the two food environments were also recorded. Larval growth was determined as a ratio of weight gained and development time: $\sum(Lw_4 - Lw_1/DT)$, expressed in mg per day.

Number of larvae that developed successfully in to adults and those died in development were recorded. Searching rate of larvae in first and fourth instar stages was measured by placing individual larva at the base of a wooden pole, 1 cm in diameter and 50 cm long. The pole was hand held vertically and inverted when the beetle reached the top. All larvae moved directly upward (geonegative and photopositive) and after 1 min the distance they had traveled was noted.

In another study, *C. transversalis* larvae were allowed to develop on abundant food and their adults were individually kept in 9 cm diameter Petri dishes in either of the two food levels. Thus ten female adults were kept individually with 35 aphids and another 10 females were kept individually with 5 aphids per adult per day. These were allowed to mate with a male every 48 h in order to maintain the reproductive vigour of beetles. Number of days taken by females to lay first egg and their reproductive period were recorded. Data obtained were subjected to student's $t$-test.

The data and results of statistical analysis are presented in Table 1. On limited food supply, larval growth was much slower and development time much longer than that recorded on abundant food supply. The larva gained, on average, 0.229 mg per day in its development to pre-pupal stage in comparison to 0.614 mg per day observed on abundant food supply. Developmental time from first instar stage to pre-pupa stage was 33.75 days for larvae kept on limited food supply and 30.37 days for larvae kept on abundant food supply.

In comparison to 10% larval mortality recorded on abundant food supply, there was 53.3 % mortality under limited food supply. Further, mortality was recorded in all the developmental stages of larvae in limited food supply while in abundant food supply the mortality was limited to first instar stage.

The first instar and fourth instar larvae after 24 h of feeding on limited food supply moved at an average speed of 3.57 cm and 78 cm per minute, respectively. When these

TABLE 1. Effect of different levels of food supplied to the different life stages of *C. transversalis* on the development parameters

| Development parameter | Mean values at two food levels | |
|---|---|---|
| | 5 aphids/day | 35 aphids/day |
| Larval weight (mg) of | | |
| First instar | $0.23^{a}$ | $0.26^{b}$ |
| Fourth instar | $7.89^{a}$ | $18.90^{b}$ |
| Development time (days) | $33.75^{a}$ | $30.37^{b}$ |
| Growth rate (mg/day) | $0.229^{a}$ | $0.614^{b}$ |
| Mortality (%) | | |
| First instar | 13.30 | 10.00 |
| Second instar | 15.40 | 0.00 |
| Third instar | 18.00 | 0.00 |
| Fourth instar | 22.00 | 0.00 |
| Total | 53.30 | 10.00 |
| Food searching speed (cm/minute) | | |
| First instar | $3.57^{a}$ | $12.60^{b}$ |
| Fourth instar | $78.00^{a}$ | $93.60^{b}$ |
| Ovary maturation time of adult female (days) | $20.50^{a}$ | $11.20^{b}$ |
| Reproductive period (days) | $15.50^{a}$ | $29.90^{b}$ |
| Longevity (days) | $47.70^{a}$ | $51.60^{b}$ |

Different letters in a line show statistically significant variation at 5% level.

were grown on abundant food supply, searching speeds were 22.6 cm and 93.6 cm per minute, respectively.

Adult females grown on limited food supply took significantly longer maturation time and shorter reproduction phase and longevity in comparison to females maintained on abundant food supply.

As prey availability in short-lived aphid colonies is variable (Mohammed and Van Emden, 1989; Helden *et al.*, 1994), individuals of coccinellid predators respond to this environment-induced variation (Obrycki *et al.*, 1998). Successful development of about 47% of the larvae into adults even on limited food supply suggested that under strong selection pressure in nature the population survive and reproduce though such individuals are likely to be less efficient as biocontrol agents (Kessler, 1971; Ives *et al.*, 1993; Agarwala, 1995). The suppressed faculties may revive under more favourable condition. Results of this study hence suggest that coccinellid predators are a dependable source of biocontrol agents for the control of aphid pests.

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